A devoicing analysis of vowel [ï] in voiceless consonant surroundings

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1. Introduction

In this experimental study, we aim to present the devoicing value of vowel [ï] > /ı/ when placed between voiceless consonants in Turkish. As well known, the devoicing in Turkish is particularly seen on the word-final position of voiceless consonants. However in our study, we observed that some phonetic parameters such as formant variations (F_0, F1, F2, F3), bark combinations, intensity values and duration values which determine the degree and value of devoicing are changed towards devoicing of vowel [ï] > /ı/. According to our consideration, these phonetic differences such as [fïf], [hïk], [çït] or [sïs] most probably are associated with such phonological reasons as manner and placement variations of Turkish consonants. Within this scope, our study's research questions are as following:

a) How does voiceless consonant surrounding effect the vowel [ï] > /ı/ towards devoicing?
b) What is the degree of devoicing in different voiceless consonantal surroundings?

2. Vowel Devoicing

'Vowel Devoicing' is a phenomenon in which high vowels drop in certain phonological environments. Kondo (1994) stated that vowel devoicing is not a clear cut distinction between voiced and voiceless sounds. Vowels in devoicing environments are phonetically realized as fully voiced vowels, partially voiced vowels and completely voiceless vowels. As well known, there are eight short vowels in Turkish phonology. All of these four Turkish high vowels can undergo the process of gradual vowel devoicing; however [u] > /u/ is slightly more resistant to devoicing than [ï] > /ı/, [i] > /i/ and [y] > /ü/. On the other hand, in an ongoing study of ours, it is detected that vowel [ï] > /ı/ is sometimes partially devoiced when it is in word-medial position. Turkish high vowel [ï] > /ı/ is located in the centre of the oral cavity (Selen 1979; Ergenç 1989; IPA 1993). The calculated formant values of the Turkish central high vowel /ï/ are shown in Table 1. The results/findings of this study is about the formant values of isolated /ï/ are consistent with the previous studies.

Table 1. Calculated F_0, F1, F2, F3 values of isolated [ï] > /ı/

	F_0	F1	F2	F3
Selen (1979)		320(m)	2000(m)	
Kılıç (2000)	145(m)	355(m)	1482(m)	2405(m)
Türk et al. (2005)		537(m) 836(f)	1578(m), 1798(f)	2722(m), 2846(f)
Davutoğlu (2010)		392	1557	
Malkoç (2011)	141(m), 227(f)	392(m), 482(f)	1444(m), 1601(f)	2547(m), 2945(f)

Studies concerning the devoicing in Turkish high vowels were mostly done by Stefanie Jannedy. The study of Jannedy (1995) in which she analyzed the vowel devoicing in Turkish is the first study on this topic. She has analyzed word-initial and word-medial positions with nine native Turkish speakers and her data displayed that various prosodic and segmental system influence the process of high vowel devoicing in Turkish. In the same study, Jannedy presented that the most devoicing is found after the least aspirated stop /p/ which suggests that there is some other overlooked contributing factor. The exception among the Turkish stops in the following environment seems to be the bilabial voiceless stop /p/ that shows somewhat less devoicing than [k] > /k/ and [t] > /t/. Both labial sound [f] > /f/ and [p] > /p/ exhibit the least amount of impact on the devoicing process.

Unlike Jannedy (1995), in our study, it is aimed to find the effect of the surrounding voiceless consonants both in preceding and following environments and specifically about the high vowel [ï] > /ı/. Moreover, this study is done with 40 native Turkish speakers which provided more data to work on.

3. Methodology

The participants of the study were 20 male and 20 female speakers of Standard Turkish. All of the participants were university students (Ankara University and Middle East Technical University) whose ages were between 18 and 25. The participants were asked to read a list of 64 CVC (*consonant-vowel-consonant*) combinations of vowel [ï] > /ı/ surrounded by voiceless consonants (Table 2).

Table 2. 64 CVC combinations of voiceless consonant surroundings

Consonant Surroundings							
çç	çf	çh	çk	çp	çs	çş	çt
fç	ff	fh	fk	fp	fs	fş	ft
hç	hf	hh	hk	hp	hs	hş	ht
kç	kf	kh	kk	kp	ks	kş	kt
pç	pf	ph	pk	pp	ps	pş	pt
sç	sf	sh	sk	sp	ss	sş	st

şç	şf	şh	şk	şp	şs	şş	şt
tç	tf	th	tk	tp	ts	tş	tt

The data were recorded and analysed in the Linguistic Laboratory of the Brain Research Centre of Ankara University with Sony IC Recorder and analyzed by Cool Edit Pro 2.1 and Praat 5.2 Software. The findings of the analysis are presented in the following order:

1. Formant values (converted to Bark and averaged over the 20 male and female speakers)
2. The intensity values
3. The duration values

4. Findings

While analyzing the findings, the values of isolated [ï] > /ı/ were taken as basis for the amount of devoicing. The significant differences were calculated according to values' distance to the mean values. For F_0, the values under 100 Hz and above 180; for F1 the values under 435 Hz and above 635; for F2 the values under 1750 Hz and above 2200 Hz; for F3 the values under 3040 Hz and above 2240 Hz were assumed as significant.

The first set of surrounding is [ʧ] > /ç/ as the preceding and the other voiceless consonants as the following. As seen in Table 3, the significant differences observed in this set are in [çït] and [çïs] combinations.

Table 3. Significant differences for [ʧ] > /ç/ as the preceding consonant

	F_0				F1		F2		F3	
	Hz (m)	Hz (f)	Bark (m)	Bark (f)	Hz	Bark	Hz	Bark	Hz	Bark
/ï/	139	255	1,36	2,49	533,50	5,02	1960,50	12,97	2743,00	15,07
[çïs]	141	254	1,38	2,48	457,57	4,36	1727,15	12,14	2868,37	15,33
[çït]	69	256	0,68	2,50	649,32	5,98	1923,50	12,85	3073,57	15,74

The next set of surrounding is [f] > /f/ as the preceding and the other voiceless consonants as the following as displayed in Table 4. The significant differences observed in this set are especially in F2 values and in F_0 value of [fıt] combination.

Table 4. Significant differences for [f] > /f/ as the preceding consonant

	F_0				F1		F2		F3	
	Hz (m)	Hz (f)	Bark (m)	Bark (f)	Hz	Bark	Hz	Bark	Hz	Bark

/ï/	139	255	1,36	2,49	533,50	5,02	1960,50	12,97	2743,00	15,07
[fïf]	138	251	1,36	2,45	487,19	4,62	1397,19	10,72	2716,90	15,01
[fïh]	143	254	1,40	2,48	472,07	4,49	1448,44	10,96	2664,52	14,89
[fïk]	120	248	1,18	2,42	475,01	4,51	1488,13	11,14	2678,15	14,92
[fïp]	137	262	1,35	2,55	486,92	4,62	1336,93	10,42	2657,94	14,88
[fïs]	125	251	1,23	2,45	442,92	4,23	1555,10	11,44	2876,00	15,35
[fït]	83	247	0,82	2,41	484,62	4,60	1598,66	11,62	2814,46	15,22

Another set of surrounding is [x/ç] > /h/ as the preceding and the other voiceless consonants as the following. As seen in Table 5, the significant differences observed in this set are especially in F2 values and in F1 value of [hïç] combination.

Table 5. Significant differences for [x/ç] > /h/ as the preceding consonant

	F_0				F1		F2		F3	
	Hz (m)	Hz (f)	Bark (m)	Bark (f)	Hz	Bark	Hz	Bark	Hz	Bark
[ï]	139	255	1,36	2,49	533,50	5,02	1960,50	12,97	2743,00	15,07
[hïç]	130	255	1,27	2,49	435,92	4,17	1885,81	12,72	2821,03	15,23
[hïf]	137	246	1,34	2,41	473,74	4,50	1440,71	10,92	2630,67	11,76
[hïh]	141	265	1,39	2,58	479,16	4,55	1578,51	11,54	2688,35	11,99
[hïk]	149	263	1,46	2,56	457,98	4,36	1617,22	11,70	2652,71	11,84
[hïp]	147	270	1,44	2,63	485,57	4,61	1457,49	11,00	2656,62	14,87
[hïs]	143	255	1,40	2,49	479,89	4,56	1606,78	11,66	2748,67	12,22
[hït]	146	260	1,44	2,53	480,03	4,56	1639,13	11,78	2732,01	15,04

The set of surrounding [k] > /k/ is as the preceding and the other voiceless consonants as the following. Like the previous two sets the significant differences observed in this set are especially in F2 and in F_0 value of [kït] and also F1 values of [kïç] combination (Table 6).

Table 6. Significant differences for [k] > /k/ as the preceding consonant

	F_0				F1		F2		F3	
	Hz (m)	Hz (f)	Bark (m)	Bark (f)	Hz	Bark	Hz	Bark	Hz	Bark
/ï/	139	255	1,36	2,49	533,50	5,02	1960,50	12,97	2743,00	15,07
[kïç]	140	256	1,38	2,50	433,23	4,14	1816,58	12,47	2710,85	15,00

[kïf]	137	254	1,34	2,48	474,33	4,51	1468,24	11,05	2649,47	14,86
[kïh]	139	260	1,37	2,54	483,56	4,59	1680,36	11,96	2623,23	14,80
[kïk]	140	268	1,37	2,61	474,32	4,51	1649,53	11,83	2652,52	14,87
[kïp]	130	233	1,27	2,28	461,41	4,39	1445,23	10,94	2640,42	14,84
[kït]	84	252	0,83	2,46	495,96	4,70	1709,50	12,07	2792,83	15,17

The other set of surrounding is [p] > /p/ as the preceding and the other voiceless consonants as the following as seen in Table 7. In this set, you may see that the significant difference is observed only in F2 values.

Table 7. Significant differences for [p] > /p/ as the preceding consonant

	F_0				F1		F2		F3	
	Hz (m)	Hz (f)	Bark (m)	Bark (f)	Hz	Bark	Hz	Bark	Hz	Bark
/ï/	139	255	1,36	2,49	533,50	5,02	1960,50	12,97	2743,00	15,07
[pïç]	139	265	1,37	2,59	460,35	4,38	1687,55	11,98	2753,60	15,09
[pïf]	135	254	1,33	2,48	470,62	4,47	1441,63	10,93	2676,02	14,92
[pïh]	144	257	1,41	2,51	498,10	4,72	1536,65	11,36	2690,65	14,95
[pïk]	138	252	1,35	2,46	482,21	4,58	1439,19	10,92	2724,62	15,03
[pïp]	144	267	1,41	2,61	498,19	4,72	1334,54	10,41	2730,44	15,04
[pïs]	136	253	1,34	2,47	462,54	4,40	1552,73	11,43	2757,49	15,10
[pït]	141	260	1,38	2,53	482,72	4,58	1494,65	11,75	2797,52	15,18

In the set of surrounding is [s] > /s/ the significant differences are observed in F2 values; F_0 and F3 values of [sïç] and F_0 value of [sït] combination as presented in Table 8.

Table.8 Significant differences for [s] > /s/ as the preceding

	F_0				F1		F2		F3	
	Hz (m)	Hz (f)	Bark (m)	Bark (f)	Hz	Bark	Hz	Bark	Hz	Bark
/ï/	139	255	1,36	2,49	533,50	5,02	1960,50	12,97	2743,00	15,07
[sıç]	98	246	0,96	2,40	567,23	5,31	1986,14	13,05	3172,84	15,93
[sïf]	138	261	1,36	2,55	488,61	4,63	1574,62	11,52	2871,72	15,34
[sïh]	133	257	1,31	2,51	486,44	4,61	1715,57	12,09	2857,53	15,31

[sïk]	120	253	1,17	2,47	457,84	4,36	1708,70	12,07	2715,37	15,01
[sïp]	142	258	1,39	2,51	499,03	4,72	1537,74	11,36	2822,24	15,24
[sïs]	105	246	1,04	2,40	559,78	5,24	1705,63	12,05	3009,73	15,62
[sït]	98	244	0,96	2,38	506,95	4,79	1596,46	11,61	2949,66	15,50

The next set of surrounding is [ʃ] > /ş/ as the preceding and the other voiceless consonants as the following. There are no significant differences observed in this set displayed in Table 8. Final set of surrounding is [t] > /t/. In this set, again the significant difference is observed in F2 values and in the values of [tïs] combination except F1 value (Table 9).

Table.9 Significant differences for [t] > /t/ as the preceding consonant

	F_0				F1		F2		F3	
	Hz (m)	Hz (f)	Bark (m)	Bark (f)	Hz	Bark	Hz	Bark	Hz	Bark
/ï/	139	255	1,36	2,49	533,50	5,02	1960,50	12,97	2743,00	15,07
[tïf]	119	257	1,17	2,50	487,06	4,62	1649,38	11,83	2892,80	15,38
[tïh]	144	261	1,41	2,54	495,20	4,69	1652,92	11,85	2748,74	15,08
[tïp]	144	273	1,41	2,66	488,03	4,63	1524,78	11,30	2844,24	15,28
[tïs]	96	257	0,94	2,51	513,30	4,85	1651,62	11,84	3040,38	15,68
[tït]	106	242	1,04	2,37	480,86	4,56	1572,87	11,51	2824,22	15,24

The intensity mean values of the overall combinations are shown in Table.10. As seen in the following, we have analyzed the gender specific intensity and we found no significant difference. And in Table.11, the minimum and the maximum mean values of the gender specific duration are shown.

Table 10. Mean values of overall combinations of intensity

	Overall Combinations
Female	76,817 dB
Male	75,541 dB
General	76,179 dB

Table 11. The minimum and maximum values of the gender specific duration

	Overall (min ~ max)
Female	0,043 ms ~ 0,127 ms
Male	0,038 ms ~ 0,088 ms

In Table.12, the duration values of female participants could be grouped into three parts according to their mean values. 19 of the 64 combinations were between 0.043 ms and 0.068 ms, 16 of the 64 were between 0.070 ms and 0.092 ms and 29 of the 64 were between 0.097 ms and 0.127 ms.

Table 12. Duration values of female participants

Mean Values	Surroundings	Ratio
0.043 ms ~ 0.068 ms	[çt], [fç], [fk], [fs], [fş], [ft], [hç], [hş], [kp], [ks], [kt], [sç], [sf], [sk], [sp], [ss], [st], [tf], [ts]	19/64
0.070 ms ~ 0.092 ms	[çk], [çp], [çş], [hp], [kk], [pk], [pp], [pt], [şk], [şp], [şş], [şt], [tk], [tp], [tt], [tş]	16/64
0.097 ms ~ 0.127 ms	[çç], [çf], [çh], [çş], [ff], [fp], [fh], [hf], [hh], [hk], [hs], [ht], [kç], [kf], [kh], [kş], [pç], [ph], [pf], [ps], [pş], [sh], [sş], [şç], [şf], [şh], [şs], [tç], [th]	29/64

On the other hand, the duration values of male participants could be grouped into two parts according to their mean values. As shown in Table 13, 38 of the 64 combinations were between 0.038 ms and 0.067 ms and 26 of the 64 were between 0.071 ms and 0.088 ms.

Table 13. Duration values of male participants

Mean Values	Surroundings	Ratio
0.038 ms ~ 0.067 ms	[çk], [çp], [çt], [çş], [fç], [fk], [fp], [fs], [fş],[[ft], [hç], [hk], [hp], [ht], [hş], [kf], [kp], [ks], [kt], [pk], [pp], [pt], [sç], [sf], [sh], [sk], [ss], [sp], [st], [şk], [şp], [şt], [tf], [tk], [tp], [tt], [ts], [tş]	38/64
0.071 ms ~ 0.088 ms	[çç], [çf], [çh], [çs], [ff], [fh], [hf], [hh], [hs], [kç], [kh], [kk], [kş], [pç], [pf], [ph], [ps], [pş], [sş], [şç], [şf], [şh], [şs], [şş], [tç],[[th]	26/64

In all of the sets, the significant differences are observed in F2 values regardless of the consonants' position, namely, it is preceding or following. In Table 14, it can be seen that the values highlighted are close to the isolated [ï] > /ı/.

5. Results

The vowel [ï] > /ı/ is devoiced when placed almost between all voiceless consonant surroundings and F2 values may display the amount and degree of devoicing (partially or fully). Devoicing is mostly seen when preceding and following the consonant [p] > /p/. Combination [pïp] has the most distinctive F2 values compared to the isolated /ï/. F_0 values of male participants are significantly lower than the isolated [ï] > /ı/, especially in the combinations following the consonant /t/. There is no significant difference in combination with the consonant [ʃ] > /ş/, either in

preceding or following environments. There is no difference between the gender specific intensity of the combinations. The range of duration values of the combinations is different for male and female participants. While the duration values of the male were grouped in two; the values of female had a third group with higher mean of duration.

Table 14. Voiceless consonants as preceding and following

F2					
	Hz	**Bark**		**Hz**	**Bark**
isolated [ï]	1960, 500	12, 975	*isolated [ï]*	1960, 500	12, 975
preceding [tʃ]	1872, 831	12, 663	*following [tʃ]*	1886, 323	12, 710
preceding [f]	1572, 273	11, 463	*following [f]*	1550, 280	11, 398
preceding [x/ç]	1650, 448	11, 798	*following [x/ç]*	1649, 980	11, 820
preceding [k]	1673, 220	11, 904	*following [k]*	1698, 945	11, 990
preceding [p]	1531, 599	11, 313	*following [p]*	1531, 281	11, 293
preceding [s]	1712, 898	12, 061	*following [s]*	1666, 414	11, 895
preceding [tʃ]	1846, 749	12, 569	*following [ʃ]*	1897, 586	12, 755
preceding [t]	1683, 371	11, 957	*following [t]*	1662, 579	11, 868

6. Conclusion

F2 may be the indicator formant which demonstrates the value of vowel devoicing. The finding of this study about the effect of consonant [*p*] > /p/ on vowel devoicing effect is consistent with the findings of Jannedy (1994). This may be explained by the phonological features of this consonant in the set of voiceless consonants as it is the only one which is plosive and bilabial. The result concerning consonant [ʃ] > /ş/ may be interpreted with the duration values of combinations having this consonant in a preceding or following environment. That is the duration values of [ʃ] > /ş/ combinations are usually in the longer value groups. Another explanation may be the consonant manner and place of the consonant.

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