

Phonological and Phonetic Contrasts on Vowel Qualities

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(English Phonetics)

0. Introduction

Phonological and phonetic features of speakers' native languages affect their foreign language pronunciation. The effects last long so even for adult learners of advanced levels, making speech without foreign accents is not an easy task. Lenneberg (1967) proposes an important biological process of language learning and calls it "a critical period." After the critical period, it becomes difficult for people to acquire languages.

Learning foreign languages before or after the critical period is a controversial issue. Learners who start learning foreign languages after the critical period tend to show errors of pronunciation on which their native language have a significant effect.

Foreign accented speech by Japanese advanced-level learners of English is observed in general societies, language classes and even academic meetings. It is caused by slight mistakes on both prosodic features, such as stress and intonation, and segmental features, such as consonants and vowels. Among these features, the vowel is focused on for the language experiment of this study.

English and Japanese have different vowel systems. English has eleven vowels and Japanese has five vowels. For example, English contrasts two vowels ([i] vs. [ɪ]) with vowel quality differences and Japanese contrasts them with short or long vowel ([i:] vs. [i]) but not with vowel quality differences.

Spoken languages are managed by people with supports of written forms. They can be visualized with types of symbols, such as their corresponding letters or phonetic alphabets. On the basis of this multilayered process of spoken languages, visualization of vowel qualities is explored for linguistic and language learning studies. Language learners are able to produce spoken forms with reading these symbols orally. Reading the symbols orally, however, does not always lead learners to accurate pronunciation.

To remedy learners' pronunciation, several tools are used. One of them is visualization of tongue shape with X-rays. This has been developed and has been made use of for a long time

in a field of speech science. As Trofimov and Daniel (1923, 25) points out, however, X ray pictures will not of itself enable the students to pronounce the sound correctly.

Visualization of language sounds and its effect for learning pronunciation of foreign language has been discussed by limited number of researchers. Among them, one of the clearest results presented by Suemitsu et al. (2015, 6) concludes that short-term training with real-time articulatory visual feedback approach improves the pronunciation of Japanese learners in acquiring the non-native vowel [æ].

Visualized vowels may not work for leaning language sounds if they are just figures with elusive scattering of dots. They are, in a way, a picture of a state that is sliced from a series of motion in three dimensions with axes of F1: openness of mouth, F2: tongue height, and time: motion of a vocal organ. As Cohn (2013, 3) explains, structured sequential sounds become spoken languages of the world, structured sequential body motions become sign languages, and structured sequential images literally become visual languages.

1. Methods

Recording of listed words and phonetic analyses of their vowels were conducted in a phonetic laboratory of Yamagata University. Formant frequencies were used for a measurement of vowel qualities. It is expected that vowels are not discriminated very well by non-native English speakers.

1.1 Participants

Three male speakers of American English (hereafter ME1, ME2 and ME3), three female speakers of American English (hereafter FE1, FE2 and FE3) participated in the experiment. They came from U.S.A. as exchange students with one year term. They were from 20 to 24 years old.

Two male Japanese students who majored in English (hereafter MJ1 and MJ2) and eight female Japanese students who majored in English (hereafter FJ1, FJ2, FJ3, FJ4, FJ5, FJ6, FJ7 and FJ8) took part in the experiment. They were from 20 to 22 years old.

1.2 Materials

Vowels [i], [ɪ], [æ], [a], [ʊ] or [u] produced by native English speakers and Japanese learners of English in a context of [h] - [d] was recorded and their F1 and F2 values were measured by the author with using Praat. Six words, "heed", "hid", "had", "hod", "hood", and "hoodoo"

were used for recording. A one-syllable word that begins with [h] and ends with [d], between which [u] was put in was not found, and so a two-syllable word, “hoodoo” was used instead.

1.3 Acoustic measurements

Files recorded in media (San Disk Extreme IV compact Flash UDMA) were put into a personal computer (Panasonic CF-W7CWU1JC). Six vowels, [i], [ɪ], [æ], [a], [ʊ] or [u], were selected for measurements. Vowel analyses measured using Praat were conducted while focusing on formants, which were concentrations of acoustic energy and the most dominant frequencies combined to produce the distinctive vowel qualities. F1, a reflection of the height of the tongue, and F2, a reflection of the location of the tongue that was the highest in production of a vowel, were measured in Hertz.

1.4 Statistical analysis

For statistical verification of the described vowel spaces, F1 and F2 values were measured. To statistically analyze these formant values, binominal distributions were based on with using z-scores. Calculation with z-scores were used with a $p < 0.05$ significance threshold to test for effects of formant values on vowel qualities.

2. Results

2.1 Phonemic contrasts

2.1.1 Minimal pairs produced by native speakers

Formant 1 and 2 values of six vowels by native speakers of American English are measured and listed in Table 1-3.

Table 1 Vowel discrimination for [i:] and [ɪ] by native speakers

	heed(S.D.)	hid(S.D.)	N	Mean	Z	P	Comparison
EM1							
F1	328(60)	509(64)	30	418	-4.63	<.000	heed<hid
F2	2608(183)	2292(207)	30	2450	-4.26	<.000	hid<heed
EM2							
F1	274(25)	413(31)	30	343	-4.78	<.000	heed<hid
F2	2624(133)	2437(111)	30	2530	-4.16	<.000	hid<heed
EM3							
F1	241(19)	399(33)	30	320	-4.78	<.000	heed<hid
F2	2258(53)	1979(75)	30	2118	-4.78	<.000	hid<heed
EF1							
F1	338(66)	486(85)	30	412	-4.37	<.000	heed<hid
F2	2659(376)	2156(177)	30	2407	-4.45	<.000	hid<heed
EF2							
F1	360(24)	525(20)	30	442	-4.78	<.000	heed<hid
F2	2773(34)	2143(74)	30	2458	-4.78	<.000	hid<heed
EF3							
F1	415(37)	583(58)	30	499	-4.78	<.000	heed<hid
F2	2908(79)	2273(97)	30	2590	-4.78	<.000	hid<heed

Table 2 Vowel discrimination for [æ] and [ɑ:] by native speakers

	had(S.D.)	hod(S.D.)	N	Mean	Z	P	Comparison
EM1							
F1	751(38)	712(29)	30	731	-3.49	<.000	hod<had
F2	1658(65)	1191(45)	30	1424	-4.78	<.000	hod<had
EM2							
F1	877(51)	597(136)	30	737	-4.65	<.000	hod<had
F2	2173(103)	1046(150)	30	1609	-4.78	<.000	hod<had
EM3							
F1	646(40)	654(35)	30	650	-0.73	NS	had, hod
F2	1708(75)	1053(85)	30	1381	-4.78	<.000	hod<had
EF1							
F1	1084(100)	888(102)	30	986	-4.43	<.000	hod<had
F2	1912(177)	1553(199)	30	1732	-4.35	<.000	hod<had

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EF2							
F1	815(40)	746(27)	30	775	-4.78	<.000	hod<had
F2	1706(69)	1291(80)	30	1499	-4.78	<.000	hod<had
EF3							
F1	965(67)	821(45)	30	893	-4.78	<.000	hod<had
F2	1626(78)	1174(70)	30	1400	-4.78	<.000	hod<had

Table 3 Vowel discrimination for [u:] and [ʊ] by native speakers

	hoodoo (S.D.)	hood (S.D.)	N	Mean	Z	P	Comparison
EM1							
F1	396(28)	490(26)	30	444	-4.78	<.000	hoodoo<hood
F2	1210(390)	1515(123)	30	1362	-3.14	<.002	hoodoo<hood
EM2							
F1	345(85)	474(52)	30	410	-4.47	<.000	hoodoo<hood
F2	1535(315)	1684(233)	30	1610	-2.66	<.008	hoodoo<hood
EM3							
F1	345(91)	425(21)	30	385	-3.15	<.002	hoodoo<hood
F2	1654(254)	1413(212)	30	1533	-3.54	<.000	hoodoo<hood
EF1							
F1	416(53)	614(32)	30	515	-4.78	<.000	hoodoo<hood
F2	1355(139)	1664(166)	30	1509	-4.06	<.000	hoodoo<hood
EF2							
F1	400(21)	549(19)	30	474	-4.78	<.000	hoodoo<hood
F2	1703(164)	1732(62)	30	1717	-0.751	NS	hoodoo, hood
EF3							
F1	396(36)	616(32)	30	506	-4.78	<.000	hoodoo<hood
F2	1579(160)	1621(210)	30	1600	-0.73	NS	hoodoo, hood

As is presented in Figure 1-3, vowel qualities by native-speakers are discriminated very well except two cases, which are produced by EF2 and EF3. In both cases, F2 values of “hoodoo” and “hood” do not show a significant difference statistically.

2.1.2 Minimal pairs produced by non-native speakers

Formant 1 and 2 values of six vowels by Japanese learners of English are measured and listed in Table 4-6.

Table 4 Vowel discrimination for [i:] and [ɪ] by non-native speakers

	heed(S.D.)	hid(S.D.)	N	Mean	Z	P	Comparison
JM1							
F1	357(18)	391(24)	30	372	-4.17	<.000	heed<hid
F2	2203(116)	2177(155)	30	2190	-1.53	NS	hid, heed
JM2							
F1	282(13)	327(24)	30	305	-4.75	<.000	heed<hid
F2	2102(160)	2022(62)	30	2062	-3.15	<.002	hid<heed
JF1							
F1	355(34)	415(47)	30	385	-3.89	<.000	heed<hid
F2	2751(654)	2772(72)	30	2762	-1.01	NS	hid, heed
JF2							
F1	439(40)	411(71)	30	425	-1.57	NS	hid, heed
F2	2913(365)	2791(449)	30	2852	-0.71	NS	hid, heed
JF3							
F1	343(34)	379(27)	30	361	-3.39	<.001	heed<hid
F2	2948(56)	2915(62)	30	2932	-2.4	<.010	hid<heed
JF4							
F1	381(40)	392(26)	30	387	-1.28	NS	heed, hid
F2	2986(56)	2804(72)	30	2895	-4.78	<.000	hid<heed
JF5							
F1	482(10)	512(38)	30	497	-3.27	<.001	heed<hid
F2	2873(165)	2802(76)	30	2837	-3.54	<.000	hid<heed
JF6							
F1	465(33)	507(62)	30	486	-2.84	<.004	heed<hid
F2	2757(186)	2483(248)	30	2620	-4.42	<.000	hid<heed
JF7							
F1	381(22)	445(34)	30	413	-4.57	<.000	heed<hid
F2	2921(33)	2819(77)	30	2870	-4.41	<.000	hid<heed
JF8							
F1	407(35)	431(26)	30	419	-2.72	<.006	heed<hid
F2	2897(65)	2745(73)	30	2821	-4.72	<.000	hid<heed

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Table 5 Vowel discrimination for [æ] and [ɑ:] by non-native speakers

	had (S.D.)	hod (S.D.)	N	Mean	Z	P	Comparison
JM1							
F1	686(38)	662(45)	30	674	-1.9	NS	hod, had
F2	1523(70)	1172(104)	30	1348	-4.78	<.000	hod<had
JM2							
F1	427(21)	492(42)	30	460	-4.48	<.000	had<hod
F2	1584(95)	1133(42)	30	1359	-4.78	<.000	had<hod
JF1							
F1	914(81)	723(79)	30	819	-4.49	<.000	hod<had
F2	2203(116)	2177(115)	30	2190	-1.53	NS	hod, had
JF2							
F1	847(29)	755(38)	30	801	-4.78	<.000	hod<had
F2	1438(71)	1275(48)	30	1357	-4.7	<.000	hod<had
JF3							
F1	819(53)	729(55)	30	774	-3.94	<.000	hod<had
F2	1599(86)	1186(72)	30	1393	-4.78	<.000	hod<had
JF4							
F1	773(11)	722(141)	30	748	-1.56	NS	hod<had
F2	1664(85)	1382(150)	30	1523	-4.55	<.000	hod<had
JF5							
F1	848(75)	743(59)	30	795	-4.27	<.000	hod<had
F2	1528(180)	1319(56)	30	1423	-4.22	<.000	hod<had
JF6							
F1	737(69)	790(47)	30	763	-3.6	<.000	had<hod
F2	1838(245)	1203(99)	30	1520	-4.78	<.000	hod<had
JF7							
F1	974(62)	831(125)	30	902	-4.76	<.000	hod<had
F2	1162(149)	1082(94)	30	1122	-2.45	<.015	hod<had
JF8							
F1	818(70)	669(44)	30	744	-4.63	<.000	hod<had
F2	1692(109)	1236(92)	30	1514	-4.78	<.000	hod<had

Table 6 Vowel discrimination for [u:] and [ʊ] by non-native speakers

	hoodoo (S.D.)	hood (S.D.)	N	Mean	Z	P	Comparison
JM1							
F1	382(16)	437(23)	30	410	-4.61	<.000	hoodoo<hood
F2	1902(180)	1601(222)	30	1852	-3.73	<.000	hood<hoodoo
JM2							
F1	322(15)	360(16)	30	341	-4.78	<.000	hoodoo<hood
F2	1238(42)	1300(74)	30	269	-3.87	<.000	hoodoo<hood
JF1							
F1	440(29)	416(33)	30	428	-2.45	<.014	hoodoo<hood
F2	1171(185)	1231(201)	30	1201	-0.483	NS	hoodoo, hood
JF2							
F1	490(27)	530(41)	30	510	-3.84	<.000	hoodoo<hood
F2	1705(76)	1654(84)	30	1675	-2.38	<.017	hood<hoodoo
JF3							
F1	354(20)	382(30)	30	368	-3.67	<.000	hoodoo<hood
F2	1519(271)	1656(256)	30	1587	-1.37	NS	hoodoo, hood
JF4							
F1	343(24)	438(33)	30	391	-4.78	<.000	hoodoo<hood
F2	1026(126)	1298(137)	30	1162	-4.64	<.000	hoodoo<hood
JF5							
F1	528(26)	511(34)	30	519	-1.92	NS	hood, hoodoo
F2	1867(133)	1650(80)	30	1758	-4.65	<.000	hood<hoodoo
JF6							
F1	427(9)	472(54)	30	449	-3.53	<.000	hoodoo<hood
F2	1666(76)	1691(90)	30	1678	-0.638	NS	hood, hoodoo
JF7							
F1	366(25)	366(30)	30	366	-0.292	<.000	hoodoo, hood
F2	1251(167)	1177(30)	30	1214	-2.05	<.040	hood<hoodoo
JF8							
F1	415(16)	458(22)	30	436	-4.52	<.000	hoodoo<hood
F2	1643(113)	1828(269)	30	1735	-3.07	<.002	hoodoo<hood

As is presented in Table 4-6, vowel qualities by nonnative-speakers are not discriminated very well. Among 60 cases, 12 cases do not show clear discrimination between minimal-paired vowels. As for “heed” and “hid”, three cases of F1 and one case of F2 do not show a significant difference between minimal-paired vowels statistically. As for “hod” and “had”, one case of F1 and one case of F2 do not show a significant difference between minimal-paired vowels statistically. As for “hoodoo” and “hood”, two cases of F1 and three cases of F2 do not show a significant difference between minimal-paired vowels statistically.

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2.1.3 Visualization of vowel qualities

Vowel discrimination for vowels by native- and nonnative-speakers is visualized with vowel spaces. There are six dots whose location is calculated with using perceptual adjusting (Story, et al. 2017, 460). Figure 1-6 presents vowel spaces by native speakers in which the scores of formant values are normalized with Bark factor equation.

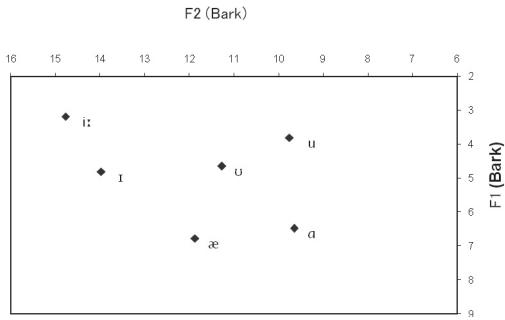


Figure 1 Vowel space by English male speaker 1

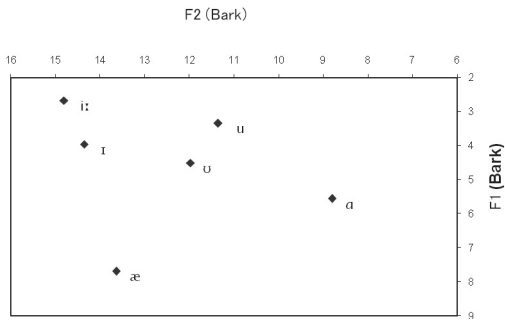


Figure 2 Vowel space by English male speaker 2

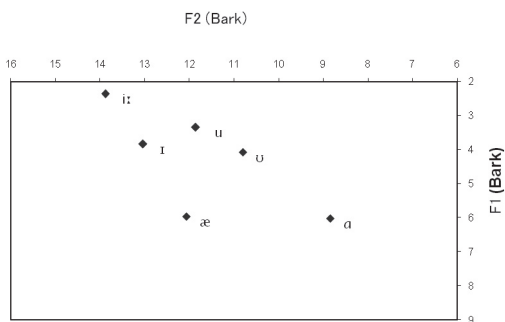


Figure 3 Vowel space by English male speaker 3

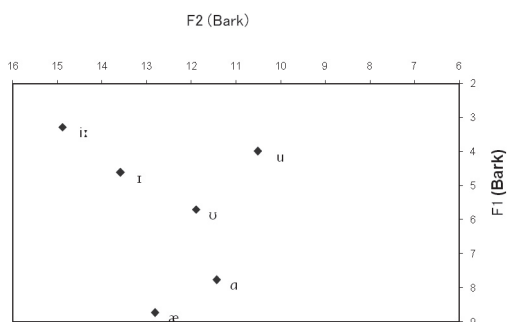


Figure 4 Vowel space by English female speaker 1

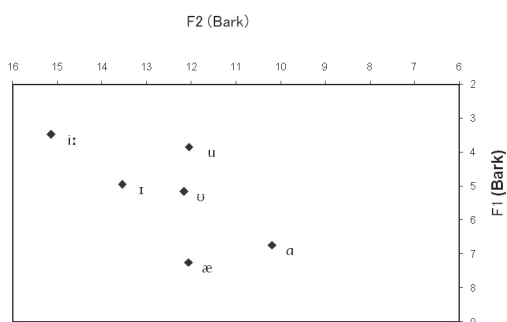


Figure 5 Vowel space by English female speaker 2

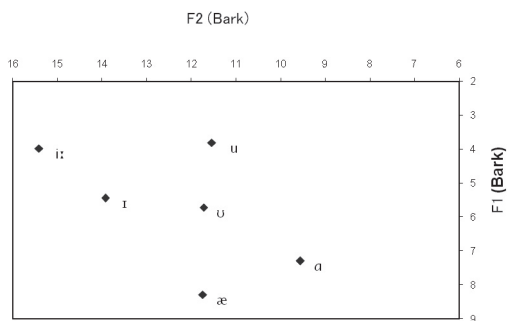


Figure 6 Vowel space by English female speaker 3

These figures present various patterns of vowel spaces. They are forming vowel spaces in which all vowels scatters very well, and that means these six vowels are produced with discrimination that also work for perception.

Figure 7-16 presents vowel spaces by nonnative speakers in which the scores of formant values are normalized with Bark factor equation.

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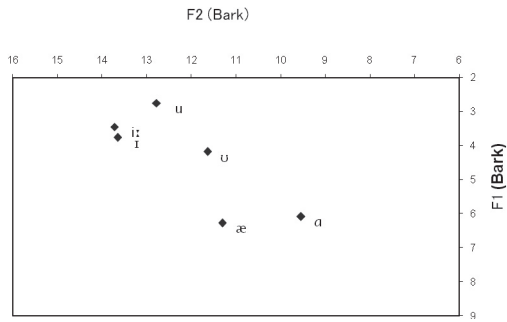


Figure 7 Vowel space by Japanese male speaker 1

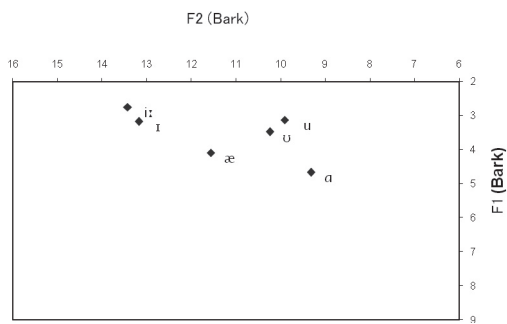


Figure 8 Vowel space by Japanese male speaker 2

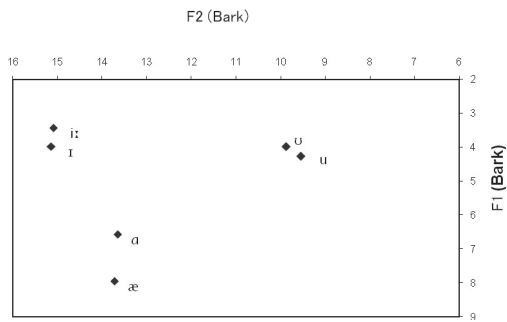


Figure 9 Vowel space by Japanese female speaker 1

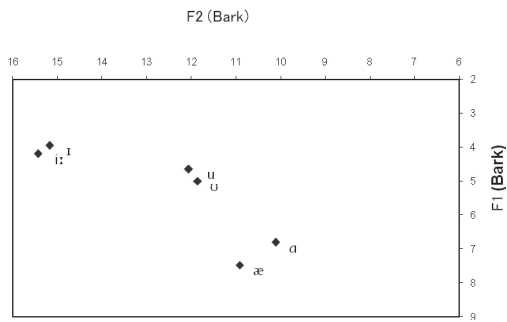


Figure 10 Vowel space by Japanese female speaker 2

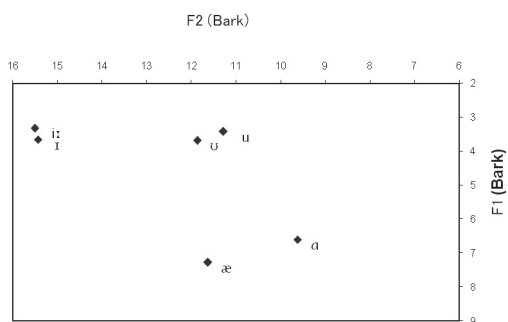


Figure 11 Vowel space by Japanese female speaker 3

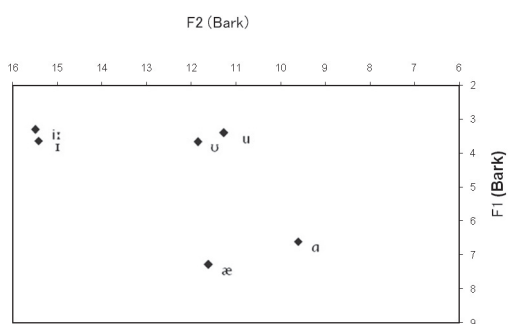


Figure 12 Vowel space by Japanese female speaker 4

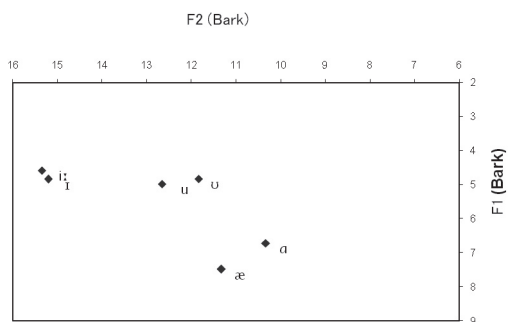


Figure 13 Vowel space by Japanese female speaker 5

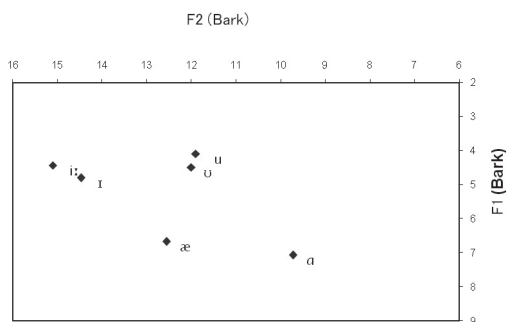


Figure 14 Vowel space by Japanese female speaker 6

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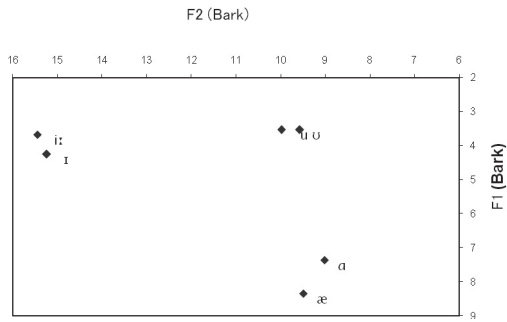


Figure 15 Vowel space by Japanese female speaker 7

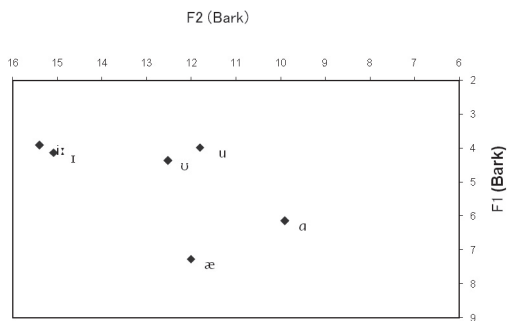


Figure 16 Vowel space by Japanese female speaker 8

These figures present several patterns of vowel spaces, most of whose two-paired vowels are not separated enough. These tendencies are quite different from native English speakers' ones.

Among 30 minimal-paired vowels, 21 minimal pairs are not discriminated very well. As for [i] – [ɪ] pairs, all 10 pairs are not discriminated. As for [æ] – [a] pairs, three pairs are not discriminated. As for [ʊ] – [u] pairs, eight pairs are not discriminated.

2.2 Phonetic contrasts

2.2.1 Differences on contexts produced by native speakers

Differences on contexts by native-speakers are presented in Table 7-9. Against the author's expectation, phonetic contrasts with F1 or F2 on contexts are not observed clearly even for utterances by native speakers.

Table 7 presents two cases, which discriminate F1 and F2 of “hid” on all three types of contexts: “said” in “What did you say?”, “did” in “Did you say ...?”, and “sAid” in “Did you say ...?”. Among 24 cases, 13 cases show hyper-articulation of vowels on one type of context; six

for interrogatives, four for repetitive statements, three for first statements.

Table 7 Vowel qualities of [i:] and [ɪ] by native English speakers in three types of context

	said (S.D.)	did (S.D.)	sAid (S.D.)	N	Mean
EM1					
heed F1	294 (6)	406 (36)	248 (8)	10	316
heed F2	2487 (46)	2841 (101)	2496 (74)	10	2608
hid F1	563 (37)	433 (17)	531 (38)	10	509
hid F2	2412 (48)	2012 (57)	2452 (44)	10	2292
EM2					
heed F1	279 (20)	259 (13)	283 (33)	10	273
heed F2	2552 (114)	2722 (103)	2600 (128)	10	2625
hid F1	438 (42)	401 (15)	400 (11)	10	413
hid F2	2358 (99)	2417 (38)	2536 (102)	10	2437
EM3					
heed F1	255 (22)	233 (17)	236 (12)	10	241
heed F2	2278 (47)	2233 (55)	2263 (52)	10	2258
hid F1	405 (14)	406 (24)	387 (49)	10	399
hid F2	1964 (45)	1983 (53)	1990 (114)	10	1979
EF1					
heed F1	326 (44)	296 (12)	393 (81)	10	338
heed F2	2656 (411)	2552 (303)	2768 (411)	10	2658
hid F1	435 (12)	599 (43)	424 (14)	10	486
hid F2	2054 (77)	2380 (79)	2036 (74)	10	2156
EF2					
heed F1	353 (16)	353 (15)	375 (32)	10	360
heed F2	2781 (28)	2750 (35)	2787 (29)	10	2773
hid F1	525 (10)	540 (13)	509 (21)	10	525
hid F2	2149 (32)	2078 (43)	2203 (78)	10	2143
EF3					
heed F1	400 (34)	412 (33)	434 (38)	10	415
heed F2	2897 (51)	2865 (92)	2964 (58)	10	2909
hid F1	618 (35)	574 (70)	556 (49)	10	583
hid F2	2189 (72)	2289 (77)	2343 (77)	10	2274

Table continued

Z (said-did)	Z (did-sAid)	Z (said-sAid)	P (said-did)	P (did-sAid)	P (said-sAid)	Comparison
-2.8	-2.8	-.153	<.005	<.005	NS	sAid, said < did
-2.8	-2.8	-.153	<.005	<.005	NS	said, sAid < did
-2.8	-2.8	-1.98	<.005	<.005	<.047	did < sAid < said
-2.8	-2.8	-2.7	<.005	<.005	<.007	did < said < sAid
-2.34	-2.1	-.459	<.019	<.036	NS	did < said, sAid
-2.66	-1.78	-.968	<.008	NS	NS	said, sAid < did
-1.98	-1.78	-2.39	<.047	NS	<.017	sAid, did < said
-1.68	-2.29	-2.7	NS	<.022	<.007	said, did < sAid

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-2.29	-653	-1.78	<.022	NS	NS	did, sAid<said
-1.68	-1.07	-1.53	NS	NS	NS	did, sAid, said
-.153	-1.58	-1.37	NS	NS	NS	sAid, said, did
-.867	-.561	-.968	NS	NS	NS	did, said, sAid
-1.98	-2.7	-.764	<.047	<.007	NS	did < said, sAid
-.969	-2.7	-2.7	NS	<.005	<.005	did, said <sAid
-.28	-.28	-1.78	<.005	<.005	NS	sAid, said < did
-.28	-.28	-.764	<.005	<.005	NS	sAid, said < did
-.153	-1.88	-1.88	NS	NS	NS	said, did, sAid
-1.98	-1.88	-.408	<.047	NS	NS	did<said, sAid
-1.78	-2.59	-1.68	NS	<.009	NS	sAid, said<did
-.28	-2.49	-1.78	<.005	<.012	NS	did<said, sAid
-.764	-1.27	-1.47	NS	NS	NS	said, did, sAid
-.663	-2.19	-2.7	NS	<.028	<.007	did, said<sAid
-1.32	-1.78	-2.65	NS	NS	<.008	sAid, did<said
-1.88	-2.29	-2.59	NS	<.022	<.009	said, did<sAid

Table 8 presents one case, which discriminate F1 of “hod” on all three types of contexts. Among 24 cases, eight cases show hyper-articulation of vowels on one type of contexts; six for interrogatives, one for repetitive statements, and one for first statements.

Table 8 Vowel qualities of [æ] and [ɑ:] by native English speakers in three types of context

	said (S.D.)	did (S.D.)	sAid (S.D.)	N	Mean
EM1					
had F1	767 (30)	723 (29)	769 (41)	10	753
had F2	1641 (35)	1642 (51)	1692 (88)	10	1658
hod F1	700 (22)	713 (24)	721 (37)	10	711
hod F2	1213 (52)	1174 (39)	1186 (36)	10	1191
EM2					
had F1	872 (50)	875 (39)	884 (64)	10	876
had F2	2133 (105)	2224 (79)	2163 (112)	10	2173
hod F1	597 (84)	604 (159)	591 (164)	10	597
hod F2	999 (155)	1072 (136)	1067 (162)	10	1046
EM3					
had F1	639 (30)	664 (35)	636 (51)	10	646
had F2	1737 (97)	1683 (53)	1705 (65)	10	1705
hod F1	639 (30)	655 (27)	643 (24)	10	646
hod F2	1061 (61)	1048 (135)	1050 (34)	10	1053
EF1					
had F1	1099 (71)	1067 (156)	1086 (51)	10	1084
had F2	1973 (104)	1774 (232)	1990 (68)	10	1912
hod F1	942 (132)	898 (70)	825 (55)	10	888
hod F2	1510 (168)	1568 (177)	1582 (254)	10	1553

EF2					
had F1	782(32)	842(20)	820(41)	10	815
had F2	1716(68)	1645(20)	1758(54)	10	1703
hod F1	730(17)	769(29)	738(18)	10	746
hod F2	1285(69)	1346(82)	1242(58)	10	1291
EF3					
had F1	921(41)	964(52)	1010(74)	10	965
had F2	1583(70)	1665(80)	1629(68)	10	1677
hod F1	812(28)	852(40)	800(50)	10	822
hod F2	1184(72)	1214(55)	1126(55)	10	1175

Table continued

Z (said-did)	Z (did-sAid)	Z (said-sAid)	P (said-did)	P (did-sAid)	P (said-sAid)	Comparison
-2.49	-2.31	-.045	<.013	<.021	NS	did < sAid, said
-.051	-1.58	-2.8	NS	NS	<.005	said, did < sAid
-1.17	-.561	-1.47	NS	NS	NS	said, did, sAid
-1.73	-1.07	-1.47	NS	NS	NS	did, sAid, said
-.051	-.663	-.663	NS	NS	NS	said, did, sAid
-1.531	-1.58	-.561	NS	NS	NS	said, sAid, did
-.663	-.459	-.764	NS	NS	NS	sAid, said, did
-.968	-.051	-1.37	NS	NS	NS	said, sAid, did
-1.22	-1.07	-.255	NS	NS	NS	sAid, said, did
-1.47	-1.17	-.968	NS	NS	NS	did, sAid, said
-1.95	-1.95	-.765	<.050	<.050	NS	said, sAid<did
-.051	-.969	-.408	NS	NS	NS	did, sAid, said
-.153	-.255	-.357	NS	NS	NS	did, sAid, said
-2.59	-2.59	-.059	<.009	<.009	NS	did < said, sAid
-.051	-2.7	-2.7	NS	<.007	<.007	sAid < did, said
-1.17	-1.53	-1.07	NS	NS	NS	said, did, sAid
-2.6	-1.88	-1.07	<.009	NS	NS	sAid, did<said
-2.7	-2.8	-1.17	<.007	<.005	NS	sAid, said<did
-2.39	-2.07	-1.07	<.017	<.038	NS	sAid<did<said
-1.88	-2.09	-1.17	NS	<.037	NS	sAid, said<did
-1.27	-1.73	-1.88	NS	NS	NS	said, did, sAid
-2.24	-.561	-1.07	<.025	NS	NS	said, sAid<did
-2.19	-2.31	-.357	<.028	<.021	NS	sAid, said<did
-1.07	-2.49	-1.83	NS	<.013	NS	sAid, said<did

Table 9 presents one case, which discriminate F2 of “hood” on all three types of contexts. Among 24 cases, eight cases show hyper-articulation of vowels on one type of contexts; five for interrogatives, one for repetitive statements, and one for first statements.

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Table 9 Vowel qualities of [u:] and [ʊ] by native English speakers in three types of context

	said (S.D.)	did (S.D.)	sAid (S.D.)	N	Mean
EM1					
hoodoo F1	392(30)	412(22)	385(26)	10	396
hoodoo F2	1460(551)	1093(221)	1078(182)	10	1210
hood F1	498(26)	479(26)	494(26)	10	490
hood F2	1511(103)	1579(161)	1455(59)	10	1515
EM2					
hoodoo F1	366(92)	294(33)	458(62)	10	373
hoodoo F2	1392(156)	1871(195)	1342(262)	10	1535
hood F1	494(50)	470(41)	458(62)	10	474
hood F2	1618(53)	1773(361)	1661(166)	10	1684
EM3					
hoodoo F1	303(14)	380(115)	351(100)	10	345
hoodoo F2	1549(198)	1885(104)	1530(264)	10	1655
hood F1	435(19)	426(20)	426(20)	10	429
hood F2	1400(132)	1547(279)	1291(114)	10	1413
EF1					
hoodoo F1	406(56)	428(24)	414(72)	10	416
hoodoo F2	1342(84)	1451(157)	1272(114)	10	1355
hood F1	616(25)	618(43)	609(30)	10	615
hood F2	1758(106)	1503(147)	1731(114)	10	1664
EF2					
hoodoo F1	419(10)	374(4)	408(10)	10	400
hoodoo F2	1815(155)	1576(87)	1719(152)	10	1704
hood F1	545(23)	555(23)	546(10)	10	549
hood F2	1734(64)	1741(84)	1722(29)	10	1732
EF3					
hoodoo F1	419(21)	386(15)	385(53)	10	393
hoodoo F2	1701(129)	1520(128)	1516(156)	10	1579
hood F1	624(36)	623(26)	601(32)	10	616
hood F2	1574(186)	1804(203)	1486(86)	10	1621

Table continued

Z	Z	Z	P	P	P	Comparison
(said-did)	(did-sAid)	(said-sAid)	(said-did)	(did-sAid)	(said-sAid)	
-1.47	-2.49	-0.612	NS	<.012	NS	sAid, said < did
-1.47	-.359	-0.612	NS	NS	NS	sAid, did, said
-1.37	-1.42	-.51	NS	NS	NS	did, sAid, said
-.968	-2.09	-2.19	NS	<.036	<.028	sAid < said, did
-1.78	-2.8	-.357	NS	<.005	NS	did, said < sAid
-2.8	-2.7	-.357	<.005	<.007	NS	sAid, said < did
-1.27	-.561	-1.68	NS	NS	NS	sAid, did, said
-1.88	-1.78	-.866	NS	NS	NS	said, sAid, did
-1.78	-.153	-1.02	NS	NS	NS	said, sAid, did
-2.8	-2.8	-.357	<.005	<.005	NS	sAid, said < did
-.663	-1.47	-.663	NS	NS	NS	did, sAid, said
-1.58	-1.78	-2.29	NS	NS	<.022	sAid < said, did

-1.27	-714	-255	NS	NS	NS	said, sAid, did
-1.58	-2.8	-1.27	NS	<.005	NS	sAid (said) <did
-.255	-.459	-1.22	NS	NS	NS	sAid, did, said
-.27	-.27	-1.04	<.007	<.007	NS	did < sAid, said
-.28	-.28	-2.09	<.005	<.005	<.036	did<sAid<said
-.259	-.209	-1.88	<.009	<.037	NS	did<sAid, said
-.663	-.561	-.051	NS	NS	NS	said, sAid, did
.153	-.255	-.866	NS	NS	NS	sAid, said, did
-.239	-.051	-1.68	<.017	NS	NS	did<said, sAid
-.229	-.153	-1.88	<.022	NS	NS	sAid, did<said
-.051	-1.68	-1.78	NS	NS	NS	sAid, did, said
-.229	-.259	-1.07	<.022	<.009	NS	sAid, said<did

2.2.2 Differences on contexts produced by non-native speakers

Differences on contexts by nonnative-speakers are presented in Table 10-12. As is expected by the author, phonetic contrasts with F1 or F2 on contexts are not observed very clearly among utterances by nonnative speakers.

Table 10 presents three cases, which discriminate F1 and F2 of “heed” and F2 of “hid” on all three types of contexts. Among 40 cases, nine cases show hyper-articulation of vowels on one type of contexts, five for interrogatives, one for repetitive statements, three for first statements.

Table 10 Vowel qualities of [i:] and [ɪ] by non-native speakers in three types of context

	said(S.D.)	did(S.D.)	sAid(S.D.)	N	Mean
JM1					
heed F1	355(9)	362(24)	353(17)	10	357
heed F2	2157(76)	2279(146)	2173(82)	10	2203
hid F1	381(9)	411(23)	381(24)	10	392
hid F2	2111(49)	2216(117)	2173(82)	10	2167
JM2					
heed F1	276(11)	288(13)	283(13)	10	282
heed F2	2166(43)	1979(231)	2161(52)	10	2102
hid F1	338(15)	298(8)	344(12)	10	327
hid F2	2014(71)	2061(38)	1990(54)	10	2023
JF1					
heed F1	346(28)	324(18)	377(32)	10	349
heed F2	2740(55)	2773(50)	2739(53)	10	2751
hid F1	420(43)	393(46)	431(49)	10	415
hid F2	2746(35)	2770(61)	2801(100)	10	2772
JF2					
heed F1	457(48)	406(23)	453(22)	10	439
heed F2	2959(253)	2693(513)	3087(113)	10	2913
hid F1	423(89)	407(18)	404(89)	10	411
hid F2	2735(485)	2798(432)	2840(471)	10	2791

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JF3						
heed F1	326 (27)	378 (24)	326 (21)	10	343	
heed F2	2985 (66)	2914 (24)	2946 (49)	10	2948	
hid F1	393 (23)	369 (19)	375 (34)	10	379	
hid F2	2950 (68)	2861 (24)	2935 (46)	10	2915	
JF4						
heed F1	398 (37)	343 (12)	402 (35)	10	381	
heed F2	2969 (76)	2997 (52)	2992 (35)	10	2976	
hid F1	400 (38)	382 (18)	394 (15)	10	392	
hid F2	2835 (39)	2997 (52)	2830 (77)	10	2887	
JF5						
heed F1	481 (13)	484 (9)	483 (7)	10	482	
heed F2	2917 (27)	2777 (266)	2925 (32)	10	2873	
hid F1	521 (42)	487 (13)	529 (41)	10	512	
hid F2	2806 (67)	2859 (50)	2740 (61)	10	2801	
JF6						
heed F1	466 (45)	460 (32)	473 (23)	10	466	
heed F2	2767 (110)	2718 (301)	2786 (78)	10	2757	
hid F1	534 (44)	484 (81)	503 (51)	10	507	
hid F2	2499 (119)	2430 (388)	2519 (171)	10	2483	
JF7						
heed F1	386 (20)	380 (24)	376 (23)	10	381	
heed F2	2920 (22)	2921 (44)	2921 (35)	10	2921	
hid F1	440 (32)	422 (29)	472 (24)	10	445	
hid F2	2866 (65)	2796 (26)	2795 (103)	10	2819	
JF8						
heed F1	405 (23)	420 (34)	397 (44)	10	470	
heed F2	2850 (44)	2966 (39)	2875 (45)	10	2897	
hid F1	429 (27)	437 (13)	428 (35)	10	431	
hid F2	2750 (65)	2729 (86)	2757 (73)	10	2745	

Table continued

Z (said-did)	Z (did-sAid)	Z (said-sAid)	P (said-did)	P (did-sAid)	P (said-sAid)	Comparison
-0.357	-0.237	-0.561	NS	NS	NS	said, sAid, did
-1.78	-1.59	-0.051	NS	NS	NS	said, sAid, did
-2.19	-2.25	-0.204	<.028	<.024	NS	said, sAid<did
-1.78	-1.59	-0.051	NS	NS	NS	said, sAid, did
-1.78	-1.17	-1.27	NS	NS	NS	said, sAid, did
-2.8	-1.98	-1.27	<.005	<.047	NS	did<sAid, said
-2.8	-2.8	-0.869	<.005	<.005	NS	did<said, sAid
-1.78	-2.65	-1.17	NS	<.008	NS	sAid, said<did
-2.29	-2.6	-0.663	<.020	<.009	NS	did<said, sAid
-1.68	-2.29	-0.296	NS	<.022	NS	sAid, said<did
-1.58	-1.58	-1.12	NS	NS	NS	did, said, sAid
-0.459	-0.764	-1.88	NS	NS	NS	said, did, sAid

-1.98	-2.8	-.4	<.040	<.005	NS	did<sAid, said
-.96	-1.88	-1.68	NS	NS	NS	did, said, sAid
-.652	-.051	-.153	NS	NS	NS	sAid, did, said
-.204	-.459	-.459	NS	NS	NS	said, did, sAid
-2.8	-2.66	-1.32	<.005	<.008	NS	said, sAid<did
-2.14	-1.68	-1.32	<.032	NS	NS	did, sAid<said
-2.66	-.816	-1.59	<.008	NS	NS	did, sAid<said
-2.8	-2.8	-.459	<.005	<.005	NS	did<sAid, said
-2.7	-2.8	-2.8	<.007	<.005	<.005	did<said<sAid
-.663	-.357	-.663	NS	NS	NS	said, sAid, did
-1.22	-1.88	-.051	NS	NS	NS	did, sAid, said
-2.8	-2.29	-.153	<.005	<.022	NS	sAid, said<did
-.561	-.119	-.255	NS	NS	NS	said, sAid, did
-2.8	-2.8	-2.8	<.005	<.005	<.005	did<said<sAid
-1.83	-2.19	-1.83	NS	<.028	NS	did, said<sAid
-1.98	-2.7	-2.19	<.047	<.007	<.028	sAid<said<did
-.77	-1.12	-.459	NS	NS	NS	did, said, sAid
-1	-.459	-.153	NS	NS	NS	did, said, sAid
-1.47	-.561	-1.47	NS	NS	NS	did, sAid, sAid
-.765	.051	-.051	NS	NS	NS	did, said, sAid
.867	.051	.459	NS	NS	NS	sAid, did, said
.459	.306	.051	NS	NS	NS	said, did, sAid
1.07	2.6	1.68	NS	<.009	NS	did, said<sAid
2.19	.306	1.88	<.028	NS	NS	sAid, did<said
-1.63	-.714	-.357	NS	NS	NS	sAid, said, did
-2.7	-2.7	-1.68	<.007	<.007	NS	said, sAid<did
-.83	-.306	-.459	NS	NS	NS	sAid, said, did
-.255	-.866	-.102	NS	NS	NS	did, said, sAid

Table 11 presents two cases, which discriminate F2 of “had” and that of “hod” on all three types of contexts. Among 40 cases, five cases show hyper-articulation of vowels on one type of contexts, and that is five for interrogatives.

Table 11 Vowel qualities of [æ] and [ɑ] by non-native speakers in three types of context

	said (S.D.)	did (S.D.)	sAid (S.D.)	N	Mean
JM1					
had F1	695 (28)	703 (33)	661 (42)	10	686
had F2	1512 (30)	1533 (119)	1524 (24)	10	1523
hod F1	683 (22)	619 (40)	684 (36)	10	662
hod F2	1212 (58)	1065 (76)	1240 (78)	10	1172
JM2					
had F1	427 (17)	430 (26)	425 (19)	10	427
had F2	1635 (60)	1497 (94)	1621 (62)	10	1584
hod F1	511 (33)	464 (49)	502 (30)	10	492
hod F2	1145 (28)	1098 (34)	1158 (32)	10	1134

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JF1					
had F1	912(76)	889(70)	943(94)	10	915
had F2	1538(100)	1386(86)	1496(168)	10	1473
hod F1	732(100)	694(56)	745(74)	10	724
hod F2	1124(54)	1096(98)	1154(74)	10	1126
JF2					
had F1	837(32)	855(29)	849(27)	10	847
had F2	1461(87)	1391(40)	1464(57)	10	1439
hod F1	745(36)	779(35)	742(34)	10	755
hod F2	1300(45)	1254(58)	1271(31)	10	1525
JF3					
had F1	796(34)	876(38)	784(31)	10	819
had F2	1616(46)	1606(50)	1576(135)	10	1599
hod F1	765(59)	694(33)	728(48)	10	729
hod F2	1224(105)	1174(38)	1161(43)	10	1186
JF4					
had F1	730(144)	685(123)	800(156)	10	738
had F2	1629(68)	1728(55)	1635(93)	10	1664
hod F1	730(144)	635(64)	800(156)	10	725
hod F2	1442(99)	1218(39)	1487(123)	10	1382
JF5					
had F1	828(83)	892(56)	823(68)	10	848
had F2	1544(161)	1515(154)	1526(233)	10	1528
hod F1	761(50)	704(33)	764(72)	10	743
hod F2	1336(56)	1297(66)	1323(44)	10	1319
JF6					
had F1	733(34)	790(71)	688(59)	10	737
had F2	1830(186)	1901(340)	1783(189)	10	1838
hod F1	787(40)	824(46)	759(35)	10	790
hod F2	1208(107)	1187(101)	1213(99)	10	1203
JF7					
had F1	1025(25)	897(22)	1001(35)	10	974
had F2	1331(74)	1154(71)	1010(33)	10	1165
hod F1	895(44)	698(127)	900(51)	10	831
hod F2	1151(67)	983(69)	1111(46)	10	1082
JF8					
had F1	856(47)	748(40)	850(63)	10	818
had F2	1709(97)	1668(73)	1701(150)	10	1689
hod F1	646(41)	691(47)	670(36)	10	669
hod F2	1245(84)	1212(113)	1250(82)	10	1236

Table continued

Z (said-did)	Z (did-sAid)	Z (said-sAid)	P (said-did)	P (did-sAid)	P (said-sAid)	Comparison
-1.58	-2.39	-1.88	NS	<.017	NS	sAid, said<did
-2.39	-1.22	-1.58	NS	NS	NS	said, sAid, did
-2.8	-2.14	-.306	<.017	<.032	NS	did<said, sAid
	-2.7	-.866	<.005	<.007	NS	did<said, sAid

-408	-225	-255	NS	NS	NS	sAid, said, did
-2.8	-2.7	-652	<.005	<.007	NS	did<sAid, said
-1.68	-1.27	-1.42	NS	NS	NS	did, sAid, said
-1.98	-2.7	-866	<.047	<.007	NS	did<said, sAid
-764	-1.88	-1.27	NS	NS	NS	did, said, sAid
-2.29	-1.68	-459	<.022	NS	NS	did<sAid, said
-561	-1.68	-663	NS	NS	NS	did, said, sAid
-968	-1.22	-968	NS	NS	NS	did, said, sAid
-765	-.255	-.969	NS	NS	NS	said, sAid, did
-1.78	-2.29	-.153	NS	<.022	NS	did<said, sAid
-1.88	-1.83	-.357	NS	NS	NS	sAid, said, did
-1.78	-.459	-.137	NS	NS	NS	did, sAid, said
-2.8	-2.8	-.663	<.005	<.005	NS	sAid, said<did
-.357	-.561	-.764	NS	NS	NS	sAid, did, said
-2.29	-.969	-.178	<.022	NS	NS	did<sAid, said
-1.17	-.561	-.168	NS	NS	NS	sAid, did, said
-1.07	-2.19	-.153	NS	<.028	NS	did, said, sAid
-2.29	-.408	-.408	<.022	NS	NS	said<sAid, did
-1.42	-2.19	-.117	NS	<.028	NS	did<said, sAid
-2.8	-2.8	-.127	<.005	<.005	NS	did<said, sAid
-1.47	-2.09	-.051	NS	<.037	NS	sAid, said<did
-.357	-.357	-.459	NS	NS	NS	did, said, sAid
-2.49	-2.29	-.255	<.012	<.022	NS	did<said, sAid
-1.58	-.714	-.204	NS	NS	NS	did, sAid, said
-2.29	-2.19	-.168	<.022	<.028	NS	sAid, said<did
-.459	-.764	-.117	NS	NS	NS	sAid, said, did
-1.17	-2.29	-.219	NS	<.022	<.028	sAid<said, did
-.255	-.051	-.051	NS	NS	NS	did, said, sAid
-2.8	-2.8	-.168	<.005	<.005	NS	did<sAid, said
-2.7	-2.8	-.28	<.007	<.005	<.005	sAid<did<said
-2.8	-2.8	-.357	<.005	<.005	NS	did<said, sAid
-2.8	-2.7	-.249	<.005	<.005	<.013	said<did<sAid
-2.8	-2.49	-.357	<.005	<.013	NS	did<sAid, said
-.663	-.866	-.347	NS	NS	NS	did, sAid, said
-1.68	-.764	-.209	NS	NS	<.037	said, sAid<did
-.663	-.561	-.153	NS	NS	NS	did, said, sAid

Table 12 presents no case which discriminate F1 or F2 on all three types of contexts. Among 40 cases, eight cases show hyper-articulation of vowels on one type of contexts, six for interrogatives, one for repetitive statements, one for first statements.

Phonological and Phonetic Contrasts on Vowel Qualities

Table 12 Vowel qualities of [u:] and [ʊ] by non-native speakers in three types of context

	said (S.D.)	did (S.D.)	sAid (S.D.)	N	Mean
JM1					
hoodoo F1	384 (21)	383 (11)	379 (18)	10	382
hoodoo F2	1876 (224)	1891 (184)	1940 (134)	10	1902
hood F1	433 (28)	430 (18)	447 (23)	10	447
hood F2	1704 (348)	1518 (97)	1581 (87)	10	1559
JM2					
hoodoo F1	331 (7)	304 (6)	332 (9)	10	322
hoodoo F2	1243 (45)	1218 (43)	1252 (34)	10	1254
hood F1	370 (13)	344 (5)	367 (15)	10	360
hood F2	1293 (75)	1243 (29)	1363 (57)	10	1300
JF1					
hoodoo F1	437 (29)	447 (27)	436 (33)	10	440
hoodoo F2	1315 (99)	981 (136)	1218 (127)	10	1171
hood F1	413 (28)	437 (35)	397 (23)	10	416
hood F2	1180 (135)	1393 (202)	1120 (161)	10	1231
JF2					
hoodoo F1	506 (11)	467 (33)	497 (13)	10	492
hoodoo F2	1716 (90)	1677 (71)	1723 (64)	10	1705
hood F1	538 (48)	506 (26)	546 (38)	10	530
hood F2	1638 (95)	1670 (79)	1658 (83)	10	1655
JF3					
hoodoo F1	358 (21)	362 (17)	342 (19)	10	354
hoodoo F2	1525 (261)	1739 (110)	1723 (64)	10	1562
hood F1	370 (34)	404 (15)	370 (27)	10	381
hood F2	1657 (304)	1705 (87)	1293 (216)	10	1552
JF4					
hoodoo F1	338 (25)	348 (17)	343 (30)	10	343
hoodoo F2	1023 (91)	970 (76)	1085 (173)	10	1026
hood F1	445 (26)	424 (35)	446 (36)	10	438
hood F2	1347 (145)	1225 (125)	1085 (173)	10	1219
JF5					
hoodoo F1	540 (28)	511 (25)	533 (16)	10	528
hoodoo F2	1876 (119)	1806 (100)	1919 (159)	10	1867
hood F1	523 (35)	498 (15)	513 (45)	10	511
hood F2	1620 (51)	1671 (59)	1659 (115)	10	1650
JF6					
hoodoo F1	431 (8)	419 (8)	430 (7)	10	427
hoodoo F2	1685 (52)	1607 (59)	1706 (80)	10	1666
hood F1	442 (18)	535 (44)	438 (18)	10	471
hood F2	1683 (81)	1718 (108)	1671 (79)	10	1691
JF7					
hoodoo F1	360 (22)	366 (24)	373 (30)	10	366
hoodoo F2	1180 (205)	1365 (79)	1208 (141)	10	1251
hood F1	375 (44)	356 (19)	367 (18)	10	366
hood F2	1107 (131)	1252 (90)	1172 (140)	10	1177

JF8					
hoodoo F1	411 (23)	412 (5)	424 (15)	10	416
hoodoo F2	1696 (88)	1554 (137)	1678 (38)	10	1643
hood F1	462 (23)	444 (15)	467 (23)	10	458
hood F2	1735 (249)	1835 (172)	1913 (352)	10	1828

Table continued

Z (said-did)	Z (did-sAid)	Z (said-sAid)	P (said-did)	P (did-sAid)	P (said-sAid)	Comparison
-1.53	-.358	-.889	NS	NS	NS	sAid, did, said
-.051	-.866	-.866	NS	NS	NS	said, did, sAid
-.204	-2.29	-1.63	NS	<.022	NS	did<said, sAid
-1.88	-1.37	-.866	NS	NS	NS	did, sAid, said
-2.8	-2.8	-.255	<.005	<.005	NS	did<said, sAid
-.971	-1.47	-.866	NS	NS	NS	did, said, sAid
-2.8	-2.7	-.534	<.005	<.007	NS	did<sAid, said
-1.58	-2.8	-1.93	NS	<.005	NS	did<said, sAid
-.866	-.562	-.102	NS	NS	NS	sAid, did, said
-2.8	-2.49	-1.71	<.005	<.013	NS	did<sAid, said
-1.78	-2.6	-1.42	NS	<.009	NS	sAid, said<did
-2.39	-2.49	-.664	<.017	<.013	NS	said, sAid<did
-2.29	-2.24	-1.42	<.022	<.025	NS	did<sAid, said
-.765	-1.58	-.153	NS	NS	NS	did, said, sAid
-1.02	-2.04	-1.22	NS	<.041	NS	did<said, sAid
-.866	-1.78	-.968	NS	NS	NS	said, sAid, did
-.306	-1.88	-1.58	NS	NS	NS	sAid, said, did
-2.29	-1.58	-.153	<.022	NS	NS	said, sAid, did
-1.98	-2.31	0	<.047	<.021	NS	said, sAid, did
-.153	-2.7	-.561	NS	<.007	NS	sAid<did, said
-1.17	-.764	-.459	NS	NS	NS	said, sAid, did
-1.27	-1.88	-.968	NS	NS	NS	did, said, sAid
-1.63	-2.5	-.357	NS	<.012	NS	did<said, sAid
-1.83	-1.88	-1.27	NS	NS	NS	sAid, did, said
-1.68	-1.63	-.764	NS	NS	NS	did, sAid, said
-1.47	-1.88	-.612	NS	NS	NS	did, said, sAid
-2.09	-.612	-1	<.037	NS	NS	did, sAid<said
-2.19	-.968	-.652	<.028	NS	NS	said, sAid<did
-2.7	-2.08	-.102	<.007	<.037	NS	did<sAid, said
-2.8	-2.66	-.764	<.005	<.008	NS	did<said, sAid
-2.8	-2.8	-.51	<.005	<.005	NS	sAid, said<did
-.764	-1.27	-.459	NS	NS	NS	sAid, said, did
-.663	-.764	-1.12	NS	NS	NS	said, did, sAid
-2.09	-2.8	-.764	<.037	<.005	NS	said, sAid<did
-.866	-1.22	-.357	NS	NS	NS	did, sAid, said
-2.29	-1.17	-1	<.022	NS	NS	said, sAid<did
-.153	-2.19	-1.47	NS	<.028	NS	said, did<sAid
-2.09	-2.19	-.764	<.037	<.028	NS	did<sAid, said
-1.42	-1.88	-.764	NS	NS	NS	did, said, sAid
-.459	-.357	-.764	NS	NS	NS	said, did, sAid

3. Discussion and conclusions

This study focuses on vowel spaces produced by native English speakers and Japanese speakers. Results show that two-paired vowels produced by Japanese native speakers are not separated enough in vowel spaces. This tendency is quite different from the one by native English speakers. Different contexts do not always produce hyper-articulation for Japanese native speakers and this tendency is also observed for native English speakers.

Vowels dotted on a vowel space are to be used for grasping characteristics of learners' pronunciation by themselves. It is expected that they sense them not only by ears but also with eyes. As Gregory (1970, 155) claims, we are able to read function from structure, and engineers can 'see' the functional significance of the parts of quite complicated systems.

One syllable words are used for oral reading except the one, which is a two-syllable word of 'hoodoo'. For a word list, a single word, not a phrase, is selected to equalize conditions of reading vowels. The author of this study, then, is recommended by other researchers to use a contraction of 'who would', for the next experiment. This comment works very well as these words are treated separately in a written form but they do not act by themselves in a spoken form. The word of 'who'd' is sure to present phonetic features of a single word.

This study focuses on phonetic features of F1s and F2s. To discriminate vowel qualities, however, duration also should play an important role. For listeners, interaction of duration values and formant ones would decide which vowels speakers are uttering.

One thing that happens to be found against the author's expectation for contrast of vowel qualities on contexts is hyper-articulation for interrogatives. In dyad, one asks to the other, for example, "Did you say "hood"?" after she/he says "What did you say?", and the other say, "I said "who'd".". This "hood" is hyper-articulated very well and it is much more than the one repeated the second time as in "I said "who'd".". This study shows the repetition does not always cause hyper-articulation of words. The condition of recording in phonetic laboratory, of course, might get rid of natural situations of hyper-articulation for repeated words.

The author of this study started exploring visualization of phonetic features, especially of vowels, for educational purposes. Vowel qualities can be depicted in vowel spaces with F1 and F2 formant values. Consonants can be depicted also in virtual consonant spaces with duration and intensity. Besides, intonation can be depicted in intonation spaces with time and intensity or pitch. With this visualization of phonetic features, learners can grasp their own pronunciation. Visualization works for clarifying phonetic characteristics of non-native language speakers' pronunciation.

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Phonological and Phonetic Contrasts on Vowel Qualities

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Abstract

This study explores vowel qualities differentiated between native and non-native speakers. Words which contain six vowels respectively, [i], [ɪ], [æ], [ɑ], [ɔ] or [u] are orally read in carrier sentences (e.g. “What did you say? I said “heed”. Did you say “hid”? I said “heed”). They include statements and interrogatives uttered between two speakers. Formant values of target vowels are measured with Praat, among which formant one and two are dealt with statistically.

Phonological and phonetic features of speakers' native languages affect their foreign language pronunciation. The effects last long and so even for adult learners of advanced levels, making speech without foreign accents is not an easy task. Lenneberg (1967) proposes an important biological process of language learning and calls it “a critical period.” After the critical period, it becomes difficult for people to acquire languages.

Effects of critical period for learning foreign languages are controversial issues. Learners who start learning foreign languages after the critical period tend to show errors of pronunciation for which their native language have a significant effect.

Foreign accented speech by Japanese advanced-level learners of English is observed in general societies, language classes and even academic meetings. It is caused by slight mistakes on both prosodic features, such as stress and intonation, and segmental features, such as consonants and vowels. Among these features, the vowel is focused on for the language experiment of this study.

English and Japanese have different vowel systems. English has eleven vowels and Japanese has five vowels. For example, English contrasts two vowels ([i] vs. [ɪ]) with vowel quality differences and Japanese contrasts them with short and long vowels ([i:] vs. [i]) without vowel quality differences.