University of Tehran press

JOURNAL OF FOREIGN LANGUAGE RESEARCH
PRINT ISSN: 2588-4123 ONLINE ISSN: 2588-7521
/https://jflr.ut.ac.ir

Learning German vowels The Impact of the Number of Vowels on the Persian Vowel space area in based on Adaptive Dispersion Theory

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ABSTRACT
In this paper, the validity of one of the principles of adaptive dispersion theory on systematizing the acoustic distance of vowels in languages, is investigated. Based on that, the more number of vowels in a vowel system of a language are, the larger area of the acoustic space will be, in order to create a perceptual distinction between vowels. This means that languages with more vowels, such as German, have greater vowel space than languages with less vowels such as Persian. To test this hypothesis, the frequency of the first and second formants, (F1, F2), of the vowels shared in Persian and German languages produced by Persian-speaking German learners in the context of words with CV:CC syllabic structure, were measured, and the area of the vowel space of Persian and German languages produced by Persian-speaking German learners at three levels of elementary, intermediate and advanced in the group of male and female were compared. In this study, the Paget and Tabain method (2005) and Becker-Crystal area indices (2010) between the number of vowels and the area of vowel space by R software and PBS mapping package, were used. The results showed that the area of vowel space only in female advanced Persian-speaking German learners is larger than Persian vowel space. This theory was confirmed only in this group; while this principle of the theory was not confirmed in other groups (elementary and intermediate) of females and in all groups of males. But the acoustic parameters, F1 and f2, in all groups are produced very different from Persian.

DOI: 0.22059/JFLR.2022.345007.961

ARTICLE INFO
Article history:
Received: 02 July 2022
Accepted: 28 September 2022
Available online: winter 2022

Keywords:
Vowel space, Vowel length, German language, Persian learners, adaptive dispersion theory

Vafa, S., alinezhad, B., & Forghani Tehrani, A. (2023). The Impact of the Number of Vowel on the Area of Persian Vowel space in Learning German vowels based on Adaptive Theory Dispersion. *Journal of Foreign Language Research*,12 (4), 536-551.

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1 Introduction

The type of pronunciation and accent is usually the first indicator that determines whether the speaker belongs to the community of native speakers or not. Repeated mispronunciations or strange word intonation in the context of the speech can prevent the correct transmission of the speaker's speech content and intention to the audience, and severely affect the success of the communication (Hadadi, Meysami, 1950, 2019). The theory that predicts the pattern of vowel distribution and the phonetic structure of the vowel systems of world languages is the adaptive dispersion theory. According to this theory on the organization of vowels, the larger number of vowels in a vowel system, such as (English and German with the largest number of vowels), the larger the area of the acoustic space will be to create a perceptual distinction between vowels. This means that if the number of vowels in a language is more, the F1(Formant1) and F2 (Formant2) are more extensive and have a larger vowel space to make a sufficient distinction between the vowels, therefore, there is a direct and positive relationship between the area of the vowel space and the number of vowels.

Theory of adaptive dispersion has three principles that deal with the phonetic structure of vowel systems of different languages and the main role of perceptual differentiation in the quality of vowel space, vowel distribution and accent recognition, and language usage. This article seeks to answer the question of how Persian vowel space size changes regarding the level of learning German (beginner, intermediate and advanced). To do this, we compared the area of vowel space of Persian and German produced by the Persian-speaking German learners in 5 monophthongs shared in the CV:CC to see whether, based on the adaptive dispersion theory, the learners produced larger German vowel space compared to Persian or not.

In learning a foreign language, the learner always struggles with various challenges and is rarely able to make significant progress in language skills without the help of experts (Parvan, Sarkar Hassan khan, 2018, 474). "Intercultural communication ability" is viewed as one of the factors that with it, the language learner can be fluent not only in language, but also in the culture of that society. The basic condition for acquiring this ability is certainly mastery of the four language skills as a whole and the acquisition of grammar and discourse skills as a part (Doostizadeh, Aruzjani, 2017, 167). In this article, the relationship between the number of vowels and the size of the vowel space in the two vowel systems of the Persian language and the standard German language, the correlation between the area indicators of the acoustic space and the structural complexity of the vowel systems (difference in the number of vowels) are compared. By drawing the vowel space of the German language in different levels of learning and the Persian language in the group of males

and females, based on F1*F2 (Harrington 2010), we compare the vowel spaces of the groups. Phonetic analysis of vowel space is done based on the method of Padget & M. Tabain (2005).

The data of this research are based on standard Persian language and standard German learners at three levels, basic, intermediate, and advanced, which were compiled by the author. Acoustic analysis to present the vowel space in Persian and German is separated by the two variables of gender (male and female) and the level of people in learning the German language, which investigates the effect of the Persian language on vowel production of German vowels, in two corpora of reading and narration text. This will show any significant impact on the more accurate learning of German by Persian-speaking students.

2 Background and Theoretical Framework

Several Iranian and foreign **research has** been conducted in different languages regarding the effect of vowels on the size of the vowel space, which we will discuss below.

2-1 Irannian research

Qaraeti (2010) investigated the changes of F1, F2 **of Persian vowels in the** stressed and non-stressed contexts and **concluded** that the place of lexical stress is on the last syllable of nouns and adjectives and the vowel space of the Persian language is more extended in the stress context than in the non-stress one. Fashendagi (2011) concluded that the position and method of consonant production affect the F2 and the most anterior vowel in **the Persian** language is /i/ and the most posterior vowel is /u/. Mohammadi (2011) **concluded** that the highest and lowest frequency of the first formant (F1) in males and females is related to the vowel / æ / and /i/ and the highest and lowest frequency of the second formant (F2), in both genders, belongs to the vowels /i/ and /u/. Estaremi and Qodssi Shahneshin (2013) took a result that according to the tests of learning progress, the topic of language teaching at the elementary level should be intensively and deeply researched to clarify the problems of measuring the learner's language learning and analyzing errors in language learning.

Alinezhad (2015) also investigated that the area of the vowel space **in the Persian** language (with six vowels) in males and females in unstressed and stressed syllables is larger than the area of the vowel space of the Mazandarani dialect which has five vowels. Also, Esfandiari and Alinezhad (2015) by the use of Neary technique (T.M. Neary) showed that females' vowel space is larger than men's both in stressed and unstressed contexts. Following the examination of the vowel space, Zare (2018) **dealt** with the issue of whether the Persian speech by the Chinese-speaking Persian learners is a part of the foreign accent in transferring the phonetic characteristics of the vowels from the mother tongue, which was used by 24 Persian speakers and 18

Chinese speakers, and it was concluded that in the Farsi speech of Chinese speakers, the F2 vowel/e/ is different from standard Farsi.

2-2 Foreign research

Pols et al (1973) by examining the variations in the frequency of formants, figured out the cause of the variations which are the source of the vowel, speaker and measurement error (Ladefoged, 1976). Potter and Steinberg (Potter & J.C. Steinberg, 1950), Peterson and Barney (G.E. Peterson & H.L. Barney, 1952) by controlling the vowel variable in the measurement error noted that the frequency of many different vowel formants in the same vowel is different for speakers. Helmi Braches (1987) states that the German language is **technically** controlled by different patterns of stress. Also, Yang and Fourakis (1989) investigated the acoustics of vowels in three languages: German, English, and Greek, and the result was that English with 11 vowels and German with 14 vowels have a more crowded and larger vowel space compared to Greek with 5 **monophthongs,** and the English and German vowels are in more outlying positions compared to the Greek vowels. Bradlow (A, Bradlow, 1996) states that based on the principles of dispersion, the more vowels in a language, the more vowel space is created. Therefore, the English language includes a wider vowel space than Spanish, and the results of Bradlow's study indicate that the area of the acoustic space in English in both types of data (CVC, CVCV) **occupies a larger area than the Spanish acoustics does.**

Livijn (P. Livijn, 2000) compares the adaptive dispersion theory and the quantum theory in examining the acoustic distribution of vowels in different systems, and by choosing 28 languages from the IRIS database, taking into account the difference of languages in terms of classification and genetics and by measuring the 5 F1, the result is that the distance between distinct vowels in lists 8-4 vowels **does** not show any tendency to increase. They increase only in the largest Vowel systems that include 11-vowel systems, and the expansion of the vowel space is observed to some extent. By comparing the production of long vowels in English-Canadian and French-Canadian bilingual and monolingual speakers, McLeod et al. (2009) found that there is no significant difference between monolingual and bilingual in **vowel** productions **of** French-Canadian as a target language **but** they found significant effect between the level of interference of the two languages in bilingual speakers. Flynn (2011) states that one of the problems in examining the vowel space is that the speakers do not have vocal tracts with the same dimensions and characteristics, and this makes it impossible to distinguish the differences in the formant values of vowels changes among speakers. Robert Klosinki (R, Klosinki, 2013) selected 21 American English people and one person from Canton to investigate the production of German vowels as a second language and the

classification of the first language of second language learners. He deals with how German learners produce vowels and integrate them with their own language, and the result shows that similar vowels are produced more similar to the new vowels of the target language, even for beginner speakers.

3 research methods

In this research, two corpora of reading and narrative texts have been used, which in terms of the method of the study have 3 parts. The first part is to provide research data, which is considered a type of field study. The second part is the acoustic study of vowels using Praat software, which is considered a descriptive and experimental type. And the third part deals with the statistical analysis of the results of the study in the framework of the adaptive dispersion theory, which is a type of analytical-statistical study.

3-1 data collection

In this research, due to the pandemic of Corona disease and the lack of availability of sufficient participants, it was not possible to consider the number of male and female participants equally, and a total of 20 participants were selected from the university of Isfahan in four groups, 5 Persian speaking people (4 men and 1 woman) **with standard Persian accent as** their first language and with an average age of 20-25 and with no other dialect involved in their speech. There were 15 German language learners (men and women) in 3 levels: basic (2 women and 3 men) with an average age of 18 to 22, intermediate (4 women and 1 man) 18 to 22**, and** advanced (3 women and 2 men) with an average age of 23 to 45. The production of these 15 German learners have been recorded and analyzed avoiding other dialects in their mother tongue. 60 sentences are considered in the reading corpus for Persian speakers. Among these sentences, 39 sentences that include monosyllabic words in the structure (consonant + vowel + 2 consonants) have been considered and analyzed, and 21 unrelated sentences are considered among the sentences so that the tone of all sentences is not the same and all sentences are not read with the same rhythm. This is because adjacent words and syntactical structure affect the tone of the sentence. For each of the 5 similar vowels in German and Persian, 5 monosyllabic words have been chosen, and the participants were asked to read each sentence 3 times with a pause between each sentence. In the narrative corpus, native Persian speakers were asked to read a Persian text once, which is in the form of **narration**, and it should be mentioned that this narration is not based on a specific text. 27 sentences are considered in the reading corpus for German speakers. In these sentences, monosyllabic words are included in the CV:CC syllabic structure, which have the intended vowels. After recording the voice of the participants, the target words were analyzed. The extraction of vowels is done by using vowels that are not influenced by

phonetic texture and speech speed (M. Joos, 1948). The influence of phonetic and phonological context on vowel characteristics in words is inevitable, so it limits the choice of context (K. Stevens, House. A.S., 1965, Manson and Solomon 2004). It is important that, in this study, we have tried to consider the maximum similarity between the shared vowels of Persian and German (a:, e:, i:, o:, u:), and the phonetic context at the minimum level of influence by using rather similar carrier sentences. It is worth mentioning that vowel length in **Persian** is dependent on a phonetic context and it plays no phonological role; but, in German, length of vowel is important phonologically, and can be short or long to change the meaning. For this reason, CV:CC syllabic structure, which has the most contextually length in Persian, has been used for comparison with long German vowels. Because the target words have the structure of CV:CC and the words before and after will have their special effect on the vowels, the Mahalanobis distance criterion (1936) was used to remove the outlier data. This criterion is used when the data has two-dimensional aspects. Statistically, outlier data means a limited number of data that are inconsistent with the normal distribution of vowels and are abnormal from the rest of the observations.

3-2 Method of checking the data

After collecting the data, Praat software version 6.1. 30 with the type of frequency spectrum display, spectrum mapping with wide band and frequency bandwidth from zero to 5000 Hz has been used for acoustic analysis of the data. The technique that Harrington used in identifying the vowel target is that the time point at which the frequency of the first formant has its maximum should be found and considered. This technique is based on the idea that the vowels reach their goal when the oral passage has the highest degree of openness, which usually coincides with the maximum frequency of the first formant (Lindblom, 1971). In this study, the target point of the considered vowels has been taken into account and the frequencies of the first and second formants have been measured. As it is said, for each vowel, 5 words in CV:CC monosyllabic structure have been selected and analyzed separately in both Persian and German languages. For example, some words and carrier sentences in Persian and German are mentioned below.

Farsi: Reza is Kord. Shiraz is in Fars. Fars is garm(hot).

German: Der Mond ist weiß. Eli wohnt in Deutschland. Er lehrt Arabisch.

R and SPSS software were used for statistical analysis of the data and the values obtained from the acoustic examination of phonetic samples. Using this software, descriptive statistics of the frequency of F1 and F2**,** and the vowel space diagram of Persian and German languages were presented. It should be noted that the statistical variables of this research are divided into different groups

such as gender, Frequency of F1 and F2 in levels of German learners including groups of beginners with A, intermediate with B, advanced with C and native Persian speakers with F are specified.

4 Data analysis

As mentioned earlier, the area indices of the vowel space based on Becker-Crystal span (2010:115) **are** a: the area of the polygon diagram b: the span of the first formant (F1), c: the span of the second formant (F2). The whole vowel space is also calculated.

4-1 Calculating the parameters of the range and area of the vowel space of Persian and German languages in two corpora of reading and fluency at different levels by gender

As we have stated before, one of the important components of sounds **is** formants **which** include important information to identify vowels. **To** investigate the area of the vowel space, the method of comparing the index average of the area of the vowel space and the frequency range in the group of males and females in Persian and German were used. Mahalanobis distance criterion (1936) was used to remove outlier data, which is used when the data are two-dimensional. Statistically, outlier data means a limited number of data that are inconsistent with the normal distribution of vowels. In this research, because vowels have two dimensions, F1 and F2, based on this criterion, if both dimensions of a vowel were **outlier**, it was removed. In Persian and German language data, the maximum frequency of the first structure for the vowel /a:/ and the minimum frequency of F1 for the vowel /i:/ have been obtained. Regarding the frequency of F2, the maximum value for the vowel /i:/ and the minimum value for the vowel /o:/ have been obtained, and the frequency range is the sum of the maximum value and the standard deviation and the difference **between** the minimum value and the standard deviation, and thus the values of min and max, it is clear that the range of vowel space is determined from the difference of these two variables in each group of formants. Based on the prediction of the theory, we expect that the German vowel space area will be larger than the area of the Persian vowel space due to the existence of more vowels in German.

In Table 1, the descriptive statistics of the frequency of F1 and F2 of shared vowels of Persian and German, which were pronounced by Persian-speaking German learners (at different basic, intermediate, and advanced levels) in reading and narration corpora are presented, taking into account the gender of both languages.

Table 1: The frequency table of the first and second formants of native Persian speakers and German learners of Persian in three basic, intermediate**,** **and** advanced groups based on gender separation in reading and narrative composition.

			F1				F2			
			A	B	C	F	A	B	C	F
S	Female	?:				613 ± 141				1285 ± 111
		a:	783 ± 107	736 ± 121	768 ± 122	879 ± 120	1504 ± 187	1531 ± 156	1426 ± 156	1786 ± 113
		e:	698 ± 44	575 ± 86	588 ± 81	541 ± 86	2124 ± 222	2093 ± 254	2217 ± 201	2048 ± 207
		i:	491 ± 56	439 ± 49	351 ± 67	302 ± 23	2405 ± 164	2526 ± 187	2406 ± 316	1771 ± 527
		o:	528 ± 49	499 ± 72	481 ± 80	464 ± 59	528 ± 49	499 ± 72	481 ± 80	464 ± 59
		u:	424 ± 43	427 ± 44	390 ± 53	335 ± 39	424 ± 43	427 ± 44	390 ± 53	335 ± 39
	Male	?:				555 ± 78				1119 ± 185
		a:	644 ± 49	580 ± 28	754 ± 104	632 ± 75	1211 ± 170	1033 ± 114	1226 ± 126	1599 ± 104
		e:	698 ± 44	575 ± 86	588 ± 81	541 ± 86	2124 ± 222	2093 ± 254	2217 ± 201	2048 ± 207
		i:	314 ± 26	306 ± 15	315 ± 53	290 ± 46	2198 ± 135	2198 ± 92	2212 ± 61	2372 ± 128
		o:	480 ± 55	474 ± 70	548 ± 62	430 ± 28	480 ± 55	474 ± 70	548 ± 62	430 ± 28
		u:	343 ± 24	355 ± 10	429 ± 51	340 ± 56	343 ± 24	355 ± 10	429 ± 51	340 ± 56
T	Female	?:				651 ± 176				1392 ± 178
		a:	875 ± 83	771 ± 82	721 ± 120	875 ± 116	1466 ± 166	1532 ± 134	1417 ± 152	1826 ± 105
		e:	668 ± 65	594 ± 78	569 ± 95	440 ± 48	1977 ± 281	2026 ± 314	2201 ± 166	2079 ± 176
		i:	464 ± 45	385 ± 46	352 ± 52	290 ± 21	2389 ± 256	2335 ± 494	2451 ± 383	2151 ± 530
		o:	1042 ± 217	1187 ± 248	1108 ± 140	1002 ± 69	1197 ± 207	1182 ± 185	1222 ± 220	1043 ± 25
		u:	1116 ± 260	1111 ± 245	1094 ± 157	1230 ± 149	1164 ± 204	1126 ± 278	1066 ± 275	1274 ± 81
	Male	?:				570 ± 90				1081 ± 164
		a:	644 ± 57	522 ± 21	644 ± 124	664 ± 59	1321 ± 167	1095 ± 60	1330 ± 352	1571 ± 91
		e:	668 ± 65	594 ± 78	569 ± 95	440 ± 48	1977 ± 281	2026 ± 314	2201 ± 166	2079 ± 176
		i:	308 ± 34	305 ± 19	341 ± 24	308 ± 41	2203 ± 172	2291 ± 73	2135 ± 110	2398 ± 218
		o:	982 ± 183	1202 ± 361	1447 ± 520	902 ± 128	1126 ± 347	1046 ± 216	1183 ± 474	921 ± 145
		u:	894 ± 136	876 ± 133	1808 ± 713	1219 ± 253	1096 ± 280	854 ± 148	1157 ± 567	1200 ± 213

From Table 1, the following results are obtained regarding the frequency of F1 and F2 in the two reading and narrative corpora in Persian and German languages:

The order of Persian and German vowels at different levels based on the ascending trend of the frequency of F1 in males and females is as follows, with abbreviations F for Persian speakers, A for Persian-speaking learners of German at the beginner level, B for Intermediate level and C for advanced level.

Reading-based orpus: **Narrative-based corpus**

[a:] female : F <A < C<B male :C <A< F <B

female :A,C< B<F male :F <C,< F

[U:] female :B<A < C <F male:C <B <A <F

female :A<C < B<F male:C<A <B <F

[o:] female :A <B <C< F male:C<A< B< F

female :C <A <B< F male:C<A< F< B

[i:]female :A<B<C<F male:C< A <B <F

female :A<B<C<F male:C< A,F <B

[e:]female :A<C<B<F male:C <A<B< F

female :A<B< C< F male:C <A<F< B

Persian and German vowels in different levels based on the ascending trend of the frequency of F2 in males and females are demonstrated below:

:**Reading-based corpus narrative-based corpus**

[a:]female : F <B<A<C male :F <C< A< B

female : F< B<A<C male :F <A<C< B

[U:] female :F<A < B<C male:C <F <A <B

female :F<A < B<C male:F < C <A <B

[o:] female :B <C <A< F male:C<B< A< F

female :C <A <B< F male:C<A< B< F

[i:]female :B<C< A< F male:F< C <B,A

female :C<A< B< F male:F< B<A <C

[e:]female :C<A< B<F male:F< C< A< B

female :C<F< B< A male:C <B<F< A

4-2 Comparison of the vowel space diagram of the Persian language with German learners at different levels of learning

For a more objective understanding of the quality of vowels in relationship with each other, a diagram is used as an acoustic tool called vowel space. This diagram is not only used for descriptive purposes but also, as Hayward points out, it includes more profound and perceptual concepts about the way vowels are produced.

4-2-1 Reading-based corpus

Table 2 shows that, in the group of female, the area of vowel space of elementary level Persian-speaking students of the German with an average value of 293,733 squared hertz is smaller than the Persian language with 332,290 squared hertz.

In diagram1, it is shown that front vowels /i:/ and /e:/ have become more anterior and rather lower in elementary level Persian-speaking learners of the German language compared to Persian speakers. The front vowel /a:/ is more posterior and closer in Persian-speaking learners of German than in Persian speakers. The back vowels /o:/ and /u:/ is reported to be roughly anterior and lower in elementary-level learners of the German language than in Persian speakers.

Table 2: Comparison of the vowel space between Persian speakers and elementary-level German students of the female group in the reading corpus

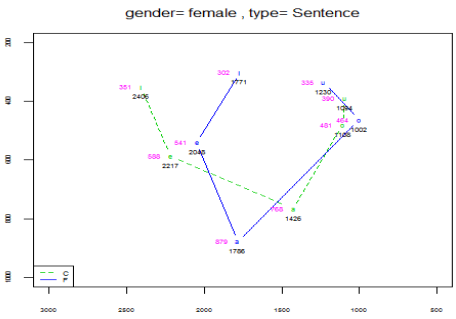
Max of area	Min of area2	StdDev of area3	Average of area4	Count of area5	Row Labels
					A
328,177	259,289	48,711	293,733	2	Female
					F
332,290	332,290		332,290	1	Female

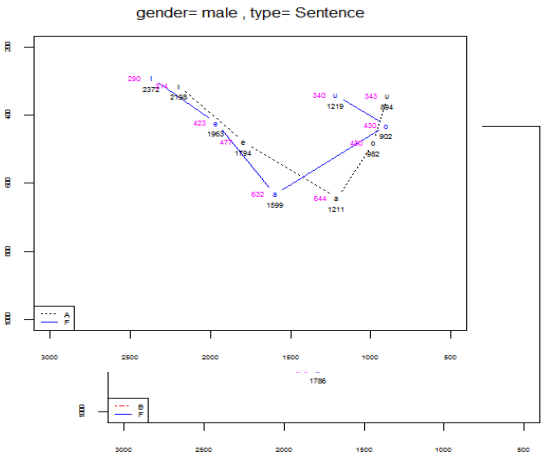
Diagram1: Comparison of the vowel space between Persian speakers and elementary-level German learners of the female group in the reading corpus

Also, at the elementary level in the male group, it was found that the German vowel space area of the Persian-speaking learners of German is larger with an average value of 226,280 squared Hz compared to Persian with 220,744 squared Hz.

In diagram2**,** the vowels /i:/, /e:/, /a:/, and /u:/ in Persian speakers are more anterior than the German learners of Persian at the basic level in males, while the vowel [o:] in Persian speakers is backer than the German learners of Persian.

Table 3: Comparison of the vowel space area between Persian speakers and elementary-level German learners of the male group in the reading corpus





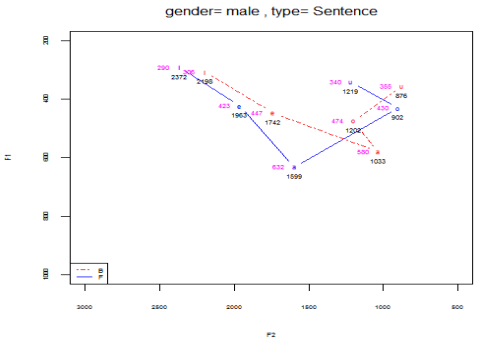


Diagram2: Comparison of the vowel space between Persian speakers and elementary-level German learners of the male group in the reading corpus

Table 4 shows, at the intermediate level, in the group of females, the German vowel space of Persian learners with an average value of 221,968 squared Hz is smaller than that of the Persian language with 332,290 squared Hz.

In diagram3, the vowels /i:/, /e:/, and/ o:/ in Persian-speaking learners of the German language at the intermediate-level are more anterior and lower in females than in Persian speakers, while the two vowels /u:/ and /a:/ are more anterior and higher in Persian speaking German learners than in Persian speakers.

Max of area	Min of area2	StdDev of area3	Average of area4	Count of area5	Row Labels
266,025	174,738				
295,206	159,269				

Max of area	Min of area2	StdDev of area3	Average of area4	Count of area5	Row Labels
					B
321,896	147,465	77,345	221,968	4	Female
					F
332,290	332,290		332,290	1	Female

Table4:

Comparison of the vowel space between Persian speakers and intermediate-level German students of the female group in the reading corpus.

Diagram3: Comparison of the vowel space between Persian speakers and intermediate-level German students of the female group in the reading corpus

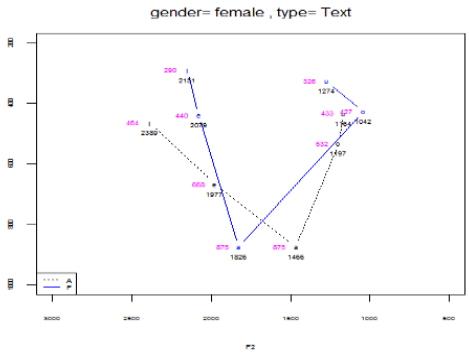
The result in table 5, at the intermediate level in the male group, showed that the vowel space of Persian-speaking learners of the German language, with an average value of 144,844 squared Hz, is smaller than that of the Persian language with 220,744 squared Hz. In diagram4, the vowels /u:/, /a:/, /e:/, and /i:/ in Persian-speaking learners of the German language at the intermediate level are more posterior and higher in males than in Persian speakers, while the vowel /o:/ in Persian-speaking learners of the German language is more anterior and anterior than in Persian speakers.Table 5: Comparison of the vowel space between Persian speakers and intermediate-level German students of the female group in the reading corpus

Max of area	Min of area2	StdDev of area3	Average of area4	Count of area5	Row Labels
					B
144,884	144,884		144,884	1	Male
					F
295,206	159,269	71,353	220,744	4	Male

Diagram4: Comparison of the vowel space between Persian speakers and intermediate-level German students of the female group in the reading corpus

At the advanced level, in the group of females, the German vowel space of

advanced Persian-speaking German learners with an average value of 351,736 squared Hz is larger than the Persian language with 332,290 squared Hz. In the diagram5, the



vowels /i:/, /e:/, and /o:/ in German learners of advanced Persian-speaking German learners are more anterior than Persian speakers, while the vowels /a:/ and /u:/ in Persian-speaking German learners are backer and higher than Persian.

Table 6: Comparison of the vowel space between Persian speakers and advanced-level German students of the female group in the reading corpus.

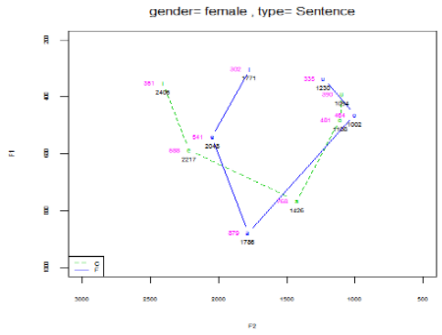


Diagram5: Comparison of the vowel space between Persian speakers and intermediate-level German students of the male group in the reading corpus

4-3-2 Narrative-based corpus

In the group of females, table 7, the vowel space of Persian-speaking learners of German at the basic level with an average value of 282,930 squared hertz is smaller than the Persian language with 345,194 squared hertz. In this space**,** diagram6, the vowels /i:/ and /o:/ in the Persian-speaking learners of German at the elementary- level are frontier than that of Persian speakers, while the vowels /e:/, /a:/, and /u:/ in Persian-speaking learners of German than Persian speakers

Table 7: Comparison of the vowel space between Persian speakers and elementary-level German learners of the female group in the narrative corpus

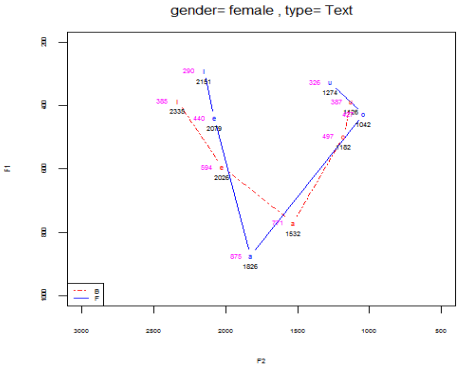
Max of area	Min of area2	StdDev of area3	Average of area4	Count of area5	Row Labels
					A
316,386	249,475	47,313	282,930	2	Female
					F
345,194	345,194		345,194	1	Female

Diagram8: Comparison of the vowel space between Persian speakers and elementary-level German students of the female group in the narrative corpus

Max of area	Min of area2	StdDev of area3	Average of area4	Count of area5	Row Labels
					C
445,157	205,628	128,162	351,736	3	Female
					F
332,290	332,290		332,290	1	Female

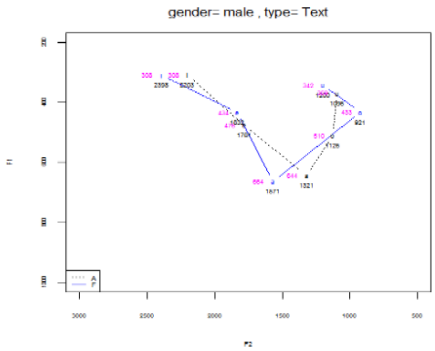
At the basic level, in the group of males, table 8 shows that the vowel space of Persian-speaking learners of German is smaller, with an average value of 182,845 Hz squared compared to the Persian language with 214,738 square Hz. In the diagram7, the

vowels /i:/, /e:/, /u:/, and /a:/ in Persian-



speaking learners of German are backer in males than in Persian speakers, and the vowels /o:/ in Persian-speaking learners of German are more anterior than Persian.

Table 8: Comparison of the vowel space between Persian speakers and elementary-level German



students of the male group in the narrative corpus.

Diagram7 : Comparison of the vowel space between Persian speakers and elementary-level German students of the male group in the narrative corpus.

In the group of females, table9, we have **concluded** that the German vowel space of intermediate-level Persian-speaking learners of German with an average value of 281,120 squared hertz is smaller than the Persian with 345,194 squared hertz. In this **space, diagram8,** the vowels /o:/ and /i:/ in intermediate-level Persian-speaking German learners in the group of females are more anterior and higher than Persian speakers, while the vowels /e:/, /a:/ and /u:/ in Persian-speaking German learners are reported to be lower than Persian speakers.

Table9: Comparison of the vowel space between Persian speakers and intermediate-level German students of the female group in the narrative corpus.

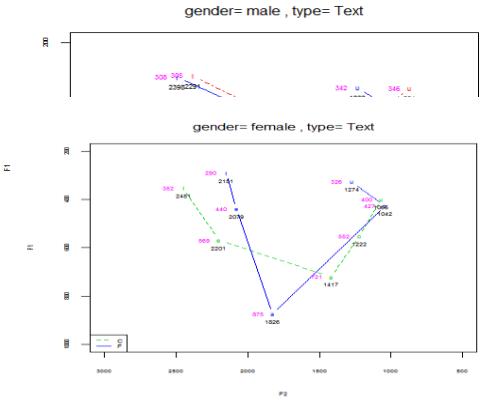
Diagram8: Comparison of the vowel space between Persian speakers and intermediate-level German students of the female group in the narrative corpus.

At the intermediate level, in the group of males, we have concluded that the vowel space of intermediate Persian-speaking learners of German with an average value of 138,668 squared Hz is smaller than the

Max of area	Min of area2	StdDev of area3	Average of area4	Count of area5	Row Labels
					B
311,430	241,572	29,027	281,120	4	Female
					F
345,194	345,194		345,194	1	Female

Persian with 214,738 squared Hz. Diagram 9 shows a very different space. The vowel of /i:/, /u:/, and /a:/ in intermediate Persian-speaking learners of German in males is backer and higher than in Persian speakers, and the vowels /e:/ and /o:/ are more anterior in Persian-speaking learners of German than Persian speakers.

Table10: Comparison of the vowel space between Persian speakers and intermediate-level German



students of the male group in the narrative corpus.

Diagram9: Comparison of the vowel space between Persian speakers and intermediate-level German students of the male group in the narrative corpus

By comparing the vowel space of the Persian language with the Persian-speaking learners of German at the advanced level in the group of females, table 10 shows that the vowel space of Persian-speaking learners of German with an average value of 313,642 squared hertz is smaller compared to the Persian language with 345 194 squared Hz. In the diagram 10, the vowels /i:/, /e:/, and /o:/ are more anterior in Persian language learners of German than in Persian speakers, and the vowels /a:/ and /u: / in Persian-speaking learners of German are backer and higher than Persian speakers.

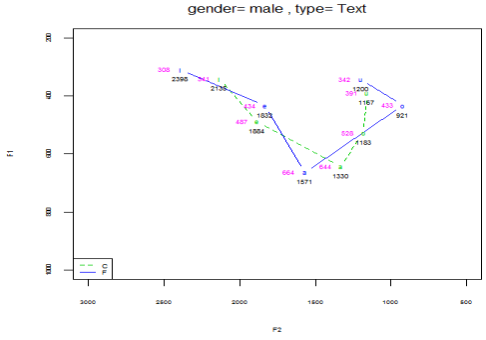


Table11: Comparison of the vowel space between Persian speakers and advanced-level German students of the female group in the narrative corpus.

Max of area	Min of area2	StdDev of area3	Average of area4	Count of area5	Row Labels
					C
424,936	182,081	122,689	313,642	3	Female
					F
345,194	345,194		345,194	1	Female

Diagram 10: Comparison of the vowel space between Persian speakers and advanced-level German students of the female group in the narrative corpus

Max of area	Min of area2	StdDev of area3	Average of area4	Count of area5	Row Labels
					B
138,668	138,668		138,668	1	Male
					F
310,177	137,326	78,332	214,738	4	Male

In the advanced level, in the group of males, the results show that the German vowel space of the Persian-speaking German learners at the advanced level with an average value of 164,859 squared hertz is smaller than the Persian language with 214,738 squared hertz. In diagram11, this **space,** the vowels /i:/, /u:/, and /a:/ in Persian-speaking German learners at the advanced level in males are backer than Persian speakers, while the vowels /o:/ and /e:/ in Persian-speaking German learners are anterior than Persian speakers.

Table 12: Comparison of the vowel space between Persian speakers and advanced-level German

Max of area	Min of area2	StdDev of area3	Average of area4	Count of area5	Row Labels
238,681	91,038	104,400	164,859	2	Male
					F
310,177	137,326	78,332	214,738	4	Male

students of the male group in the narrative corpus.

Diagram11: Comparison of the vowel space between Persian speakers and advanced-level German students of the male group in the narrative corpus.

In diagram 12, the vowel space area of the German language in Persian-speaking learners of German with the Persian language is displayed in narrative and reading corpuses. As can be seen, the area of vowel space of all vowels in females, are more than that of males. The arrangement of the levels of German learners and native Persian speakers according to the vowel space area based on the ascending process is as follows:

Female in reading-based corpus: C> F> A> B

female in narrative-based corpus= F> C> A> B

Male in reading-based corpus: A> F> B> C

Male in narrative-based corpus= F> A> C>B

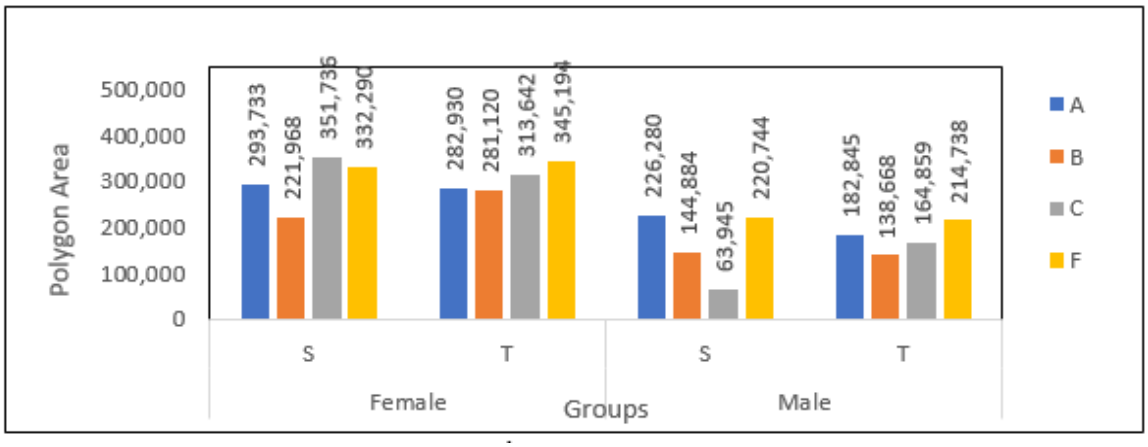


Diagram 12: Vowel space area in reading and narration in the group of males and females

5 The results of the conducted tests

To investigate the key prediction of the adaptive dispersion theory, the area of the vowel space of the Persian language has been compared with 5 similar long vowels of the German language produced by Persian-speaking German learners based on Becker-Krystal (2010). The "General linear model by analysis of variance for one dependent variable" was conducted to find out how different factors such as gender, corpus type**,** and level of learning have affected the F1 and F2 results of each vowel. The results of this study indicate that when normalization leads to the reduction of variance, it leaves the most impact on group classification and leads to better classification of phonetic groups.

In this test, F indicates the value of the test statistic, which has Fisher distribution (with **the degree** of freedom) and df2. The interaction effect of two factors is significant when the value of sig is less than 0.05, and hypothesis will be approved. If the sig is more than 0.05, the effect is not significant and we reject the hypothesis. The test statistic for gender is equal to 25.543, which has a fisher distribution with degrees of freedom 1 and 34, and its sig is less than 0.05 and so gender is a significant factor, table 12.

Table 13: Multi-way analysis of variance (univariate) for the vowel space of Persian and German at different levels in females and males.

Dependent Variable: area

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
level	37735501202.885	3	12578500400.962	2.147	.112
gender	149650250147.541	1	149650250147.541	25.543	.000
type	599958226.897	1	599958226.897	.102	.751
Error	199201236183.913	34	5858859887.762		

6 Results

In this research, we have investigated the effects of vowel space changes in learning German language by Persian learners. Because the number of vowels in German is more than Persian, we have expected gradual greater area size of the vowel space during learning German. But according to the statistical analysis, we can maintain only the hypothesis that the female group produced a larger vowel space in the reading corpus. But the most important thing is that the acoustic parameters, F1 and F2, are produced much more different from Persian vowels. It should be noted that F1 has an inverse relationship with the height of the tongue. As the height of the tongue decreases. To increase F1, the tongue must be lowered. F2 is directly related to back or front position of the tongue, the more front of the tongue, the higher f2 will produced.

Correlation study of F2 with the degree of posteriority indicate that F2 is higher for front vowels than for back vowels. In other words, the more front produced in the oral cavity, the higher the frequency of its second formant, and the more back the oral cavity, the lower the F2 of the vowel.

Therefore, the low front vowel /a:/, the mid front vowel /e:/ and front high vowel /i:/ have a higher F1 than the back vowels /o:/, /u:/. The results show that and the, the vowel /a:/ is the most open in the group of female German learners**,** and the vowel /i:/ is the most closed vowel in the group of male German learners. We can conclude that the prediction of the theory is confirmed only in the group of Persian-speaking German learners at an advanced level of the female group in the reading corpus. But this theory has not been confirmed in other groups which produce much more different formants vowels from the Persian vowels but still produced smaller vowel space.

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