

A Timeline for Acquisition of Farsi Consonants: A First Language Acquisition Corpus-based Analysis

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Abstract—This study is one of the first endeavors in the realm of Farsi acquisition as the first language. The one-year utterances of five Iranian children were meticulously observed to determine the onset of steady perfect articulation of each consonant. The corpora were available from CHILDES which is the largest database for children's corpus-based studies. Corpora analysis revealed that [w] and [ʒ] had been perfectly pronounced before the study initiated; [f] was accomplished before the 40th month; [m] and [x] were perfectly enunciated in the 42nd month while the pronunciation [v] was idealized in the 44th month along with [b], [d], [h] and [g]; [t], [n] and two approximants were perfectly produced in the 46th month and [s] got its steady idealized pronunciation in the 48th month; [r] in addition to affricates and [z] and [ʃ] were in the process of completion when the inquiry terminated. 8 consonants from a total of 23 found their idealized articulations between the 43rd and 46th months of age.

Index Terms—first language acquisition, consonant acquisition, corpora analysis, CHILDES corpora

I. INTRODUCTION

Chomsky (2004) emphasized that for comprehending what constitutes linguistic knowledge, it is crucial to know phonological representations and their growth stages. As Dresher (2004) mentioned, in the seventies, children were supposed to acquire morpheme structure conditions and the active phonological rules that relate underlying forms to surface forms. In the eighties, the focus was on phonological representations that children had to acquire. In the nineties, child phonology was about defining the constraints that characterize children's productions (as cited in Fikkert, 2007). One of the few attested points regarding the development of children's phonology is that "sounds precede words in acquisition; furthermore, children acquire vowels prior to consonants whilst naming words are more frequently articulated than action words" (Pinker, 1994).

Very few experiments have been successfully conducted on children to test the development of phonology due to their short memory coverage and their eagerness to do the test (Prince & Smolensky, 1993). The shortage of original data and longitudinal studies can be consumed as another factor which has hindered the detailed analyses of children articulation development studies (McWhinney, 2010). Few studies have viewed developing the whole phonological system. This article is one of the first attempts which tapped on the acquisition of Farsi as the first language through scrutinizing considerable corpora and presents a longitudinal descriptive report of five Iranian children's commencement and order of proper consonant appearance during one year of inspection. Thirty audio files were transcribed and analyzed for each of the subjects in order to

- Determine a timeline of her consonants' articulation development, and
- Determine the consonantal category of (un)challenging consonants for her to pronounce.

II. LITERATURE REVIEW

Parental diaries are deeply-rooted milestones in the literature of first language acquisition (e.g., Preyer 1889; Stern and Stern, 1907; Grégoire, 1937; Velten, 1943; Leopold, 1947). These diary studies which had larger focuses than just language were not that systematic even though they benefitted from large samples such as Templin (1957) in which 430 subjects participated.

This assumption that child and adult phonology are made up of the same ingredients, has provoked the researchers to investigate the evolutionary survey of children's phonology development. For example, Dresher (2004) by proposing *Continuous Dichotomy Hypothesis* confirmed that the sounds children produce at the initial stage of language

acquisition are the improper variants of phonemes adults articulate in their adulthood. So, gaining knowledge about the time and the quality with which children acquire the correct articulations of phonemes may provide the researcher with insightful information regarding the articulation theories of phonology and even speech therapy enquiries.

Consonant acquisition

Many researchers (e.g. Holzman, 1997; Foster-Cohen, 1999) suggested that initial consonant sounds are often those linked to lips because the children try to imitate their parents facial expressions witnessed during face to face interactions. This may accentuate the roles of care-takers and parents who are usually present in the immediate environment. Evans-Morris (1998) also mentioned that consonants will be acquired much sooner than the vowels through interactional activities such as plays. Again this happens by imitating the peers in the environment when the time is right.

On the other hand, Fikkert and Levelt (2004) focusing on the acquisition of place of articulation, found that at early stages of acquisition, for articulating the words consisted of consonants and vowels that shared the same place of articulation vowel sounds were prior. At subsequent stages, the vowel could be specified independently from the consonants, and later, the consonants in a word could also have different places of articulation. At this stage, a pattern emerged in which specific places of articulation were preferred in specific prosodic positions. Dutch children preferred labials in word-initial position, while they tended to avoid words beginning with dorsals, which is reminiscent of the word templates. Another important finding was that children were initially very faithful to the place of articulation make-up of target words (Vihman et al., 1994), and that ‘incorrect’ renditions only occurred at a later stage. The unfaithfully produced words often resulted in labial-initial child’s productions, where the adult target was labial-final; for instance, ‘soap’ produced as [fep] (as cited in Fikkert, 2007).

III. METHOD

A. *Subjects*

The subjects were five roughly 3-year-old Persian children whose exposures to other children were limited because she was cared for at home. During the 12 months of data collection, the subjects have been in touch with their parents and some temporal guests at home. The subjects’ parents began diaries of their language productions from the January of 2013 until the December of the same year during which 30 one-hour audio files were record in “wav” format for each children which are available from “<http://byu.corpora.edu>”. With the aid of “Phon” each one of the subjects’ actual utterances were transcribed in IPA symbols while its orthography, morphology and its target IPA symbols were discernible on the screen.

B. *Instruments*

“Phon”, a transcribing software designed at Memorial University of Canada (MUN), seems to be a way out from the practical problems encountered in phonological corpus-based case studies. It makes it possible to test most current hypotheses against a large body of data. “Phon”, in addition to the morphology and the IPA target transcription of every utterance and a media player, is also equipped with a smart IPA menu and a syllabification processor; it uses different colors for onsets, vowels and codas and tenders the deviations of the actual utterances from the target ones. This software has a distinctive ability for transcribing validation, analyzing the corpora and reporting the results.

C. *Procedure*

After the audio files were collected, transcribing began and lasted 4 months of hard work. All utterances were transcribed except for the subject’s whining, yelling and other unidentifiable declarations. Then, the transcribed corpora were given a double check by two post-graduate students of linguistics. Furthermore, they have been validated by “Phon” itself. As the next step, corpora analysis started. “PhonQuery” run for consonant articulation. The number and the percentage of correct and incorrect articulation were determined for each consonant. It is worth mentioning that “voice” was not regarded as a distinctive phonological feature in quantification of acceptable productions of a consonant (e.g., [s] was considered as the acceptable pronunciation of [z] or [d] was regarded as the proper enunciation of [t] due to the common place and manner of articulation). This made it possible to have a quantitative analysis of correct verbalization and consequently, an acquisition curve for each consonant and its consonantal category based on place and manner of articulation.

IV. DATA ANALYSIS AND DISCUSSION

The very first observation was that articulation of all consonants improved during the year of enquiry. In the following lines the subjects’ advancements are illustrated for each consonantal category.

Plosives

Bilabial plosives_ Subjects’ correct articulation of [b] had been started before the age of three, before the commencement of the study; [b] articulation was acceptable from the beginning of the enquiry but it was accomplished perfectly at the average age of 3.8 when the twentieth audio file was being recorded for the subjects. Considering the fact that the only distinctive phonological feature between [b], [p], [β] and [β̞] is “voicing”, all these variations were also

considered as the acceptable articulation of [b]. As it can be seen in Table 1, as the time passed the accuracy of [b] pronunciations increased while the number of [b] deletions declined.

TABLE 1.
VARIATIONS IN ARTICULATING [b]

Audio file	1-5	6-10	11-15	16-20	21-25	26-30	Total
Variations							
b → b	102	297	192	415	492	521	2019
b → ʋ	1	0	1	0	0	0	2
b → β	3	1	14	4	0	0	22
b → p	9	1	0	1	0	0	11
b → d	2	0	0	0	0	0	2
b → g	1	0	0	0	0	0	1
b → k	1	0	0	0	0	0	1
b → m	2	2	1	0	0	0	5
b → n	2	1	1	1	1	1	6
[b] deletion	18	3	3	2	0	1	27
Percentage	82%	95%	97%	99%	100%	100%	97%

The correct pronunciation of the other bilabial plosive, [p], had been appeared before the age of three similar to [b]. The only difference was that its enunciation idealized sooner than [b] around the age of 3.6 in the fifteenth audio file while pronunciation of [b] was better when the study initiated. Likewise, [b] was considered an acceptable pronunciation of [p]. Table 2 depicts what the subjects produced on average for [p]. Corpora analysis revealed that “bilabial plosives” were not challenging at all for the subjects; 97% of all [b] like [p] articulations were accurate. This certifies what Foster-Cohen (1999) and Evans–Morris (1998) suggested about the acquisition of “labials” (section 2.2.). Figure 1 depicts the acquisition curves of these two consonants.

TABLE 2.
VARIATIONS IN ARTICULATING [p]

Audio file	1-5	6-10	11-15	16-20	21-25	26-30	Total
Variations							
p → p	15	19	19	34	77	87	251
p → b	16	8	17	0	2	0	43
p → d	0	0	1	0	0	0	1
[p] deletion	6	1	0	0	0	0	7
Percentage	77%	95%	99%	100%	100%	100%	97%

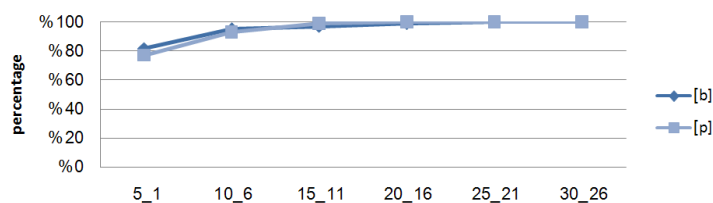


Figure 1. The acquisition curves of bilabial plosives

Alveolar plosives_ Similar to “bilabials”, the subjects had had good pronunciations of [t] and [d] in the beginning of the study. Articulations of [t] became perfect around the age of 3.10 in the twenty fifth audio file. Due to minute phonological distinctions, consonants [d], [d] and [t] were assumed as the acceptable variations of [t]. Overall, 89% of all [t] articulations were perfect and omitted [t] were reduced in number as the study advanced. Table 3 shows the variations of [t] in the subject’s utterances.

TABLE 3.
VARIATIONS IN ARTICULATING [t]

Audio file	1-5	6-10	11-15	16-20	21-25	26-30	Total
Variations							
t → t	26	59	96	82	127	202	592
t → d	18	8	1	1	0	0	28
t → dʰ	4	0	1	0	0	0	5
t → t̪	36	8	17	11	0	0	64
t → g	1	0	0	0	0	0	1
t → j	0	1	0	0	0	0	1
t → s	4	0	0	0	1	0	5
t → e	6	4	0	0	0	0	10
t → ts	1	0	0	0	0	0	1
t → tʃ	4	0	1	0	0	0	5
t → θ	1	0	0	0	0	0	1
[t] deletion	25	17	10	6	8	1	68
Percentage	64%	78%	85%	93%	94%	100%	89%

Developmental articulation of [d] was similar to that of [t]; both had been appeared before the year of observation but [d] was idealized sooner around the age of 3.8 in recording the twentieth file of the corpora. [t], [d] and [d] were deemed to be proper articulations of [d]. Generally, [d] was spoken better than [t] by the overall correct articulations of 96%. Table 4 depicts variations of [d] in detail. Omission of [d] like [t] decreased throughout the year of observation.

TABLE 4.
VARIATIONS IN ARTICULATING [d]

Audio file	1-5	6-10	11-15	16-20	21-25	26-30	Total
Variations							
d → d	107	243	177	469	643	440	1683
d → ḍ	26	6	3	2	0	0	37
d → ḍ̣	12	4	12	2	0	0	30
d → t	12	6	2	2	1	2	23
d → b	0	7	0	1	0	0	8
d → f	0	1	0	0	0	0	1
d → g	1	0	0	2	0	0	3
d → j	4	1	1	0	0	0	6
d → l	1	0	0	0	0	0	1
d → n	1	0	1	0	0	0	2
d → s	0	0	1	0	0	0	1
d → v	1	0	0	0	0	0	1
d → z	1	0	0	0	0	0	1
d → dz	1	1	0	0	0	0	2
d → β	0	1	0	0	0	0	1
[t] deletion	28	17	7	10	3	1	66
Percentage	79%	79%	95%	98%	100%	100%	96%

“Alveolar plosives”, like “bilabial plosives” were being produced before the initiation of the inspection and were acquired easily by the subject during the year of the study; 93% of all articulations of [d] and [t] were acceptable. Figure 2 demonstrates the acquisition curves of these two consonants.

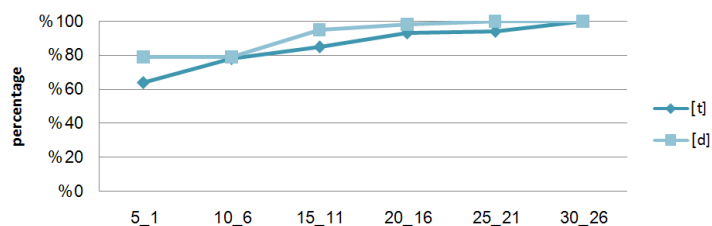


Figure 2. The acquisition curves of alveolar plosives

Velar and uvular plosives_ As the corpora analysis revealed articulations of [k] and [g] as velar plosives and [q] as the sole uvular plosive of Farsi were as unchallenging as “bilabials” and “alveolars”; 90% of all attempted [k]s were pronounced correctly. Although the subjects’ productions of [k] were not proper in the first five audio files (average of 50%), their acquisition rates were so amazing that their full accomplishment of [k] occurred around the age of 3.6 in the fourteenth file. Velar plosive [g] was also viewed as the proper articulation of [k] due to their common phonological features. Few instances of “velar fronting” were seen whose frequency reduced as the study advanced. “Velar fronting” happened for about 6% of all [k] where the subjects produced [t] instead of [k]. (1) and (2) show two instances of [t] to [k] substitutions. Table 5 shows the variations of [k] in the subjects’ utterances in detail.

- (1) ['ketab] /'tetaβ/ (book) (File No. 2 # subject no. 3)
 (2) ['komæk] /'tomæt/ (help) (File No. 6 # subject no. 4)

TABLE 5.
VARIATIONS IN ARTICULATING [k]

Audio file	1-5	6-10	11-15	16-20	21-25	26-30	Total
Variations							
k → k	24	70	74	104	129	205	606
k → g	12	5	0	1	1	1	20
k → d	1	0	0	0	0	0	1
k → h	1	0	0	0	0	0	1
k → t	18	19	5	0	0	2	44
k → e	2	0	1	0	0	0	3
k → q	1	0	0	0	0	0	1
k → y	1	0	0	0	0	0	1
k → f	2	0	0	0	0	0	2
k → ʃ	1	0	0	0	0	0	1
k → χ	1	0	0	0	0	0	1
[k] deletion	8	5	2	1	0	0	16
Percentage	50%	68%	90%	100%	100%	100%	90%

Few instances of “velar fronting” were observed for [g]; 7% of all tried [g]s were replaced by [d]. The subjects’ productions of [g] were also reasonably good but not as good as [k] (86% of all attempted [g] were acceptably pronounced). [g] accomplishment occurred in the twenty first file around the age of 3.9. Velar omission was drastically decreased during the year of observation. (3) and (4) are two examples of [g] fronting. Table 6 presents the subjects’ [g] productions in detail.

- (3) [ˈgush] /ˈduʃ/ (ear) (File No. 7 # subject no. 1)
 (4) [ˈgesse] /ˈdesse/ (story) (File No. 11 # subject no. 6)

TABLE 6.
VARIATIONS IN ARTICULATING [g]

Audio file	1-5	6-10	11-15	16-20	21-25	26-30	Total
Variations							
g → g	36	41	36	31	49	85	278
g → k	3	7	3	1	4	1	19
g → d	5	5	10	1	3	0	24
g → q	2	1	2	0	0	0	5
g → ŋ	1	8	1	0	0	0	10
g → d̪	1	0	0	0	0	2	3
g → y	2	1	3	0	0	0	6
g → dʒ	0	1	0	0	0	0	1
g → χ	1	0	0	0	0	0	1
[g] deletion	5	3	2	1	0	1	12
Percentage	69%	72%	74%	93%	100%	100%	86%

Productions of [q] as the only uvular plosive in Farsi were by far more challenging than other plosives for the subjects. Only 36% of attempted [q] were pronounced properly and its productions were idealized around the age of 3.11 in the twenty seventh file. Considerable numbers of the all tried [q] were pronounced [g] and [ɣ] (35% and 13% respectively). Table 7 shows what the subjects produced for [q] during the course of observation on the average.

TABLE 7.
VARIATIONS IN ARTICULATING [q]

Audio file	1-5	6-10	11-15	16-20	21-25	26-30	Total
Variations							
q → q	4	5	12	8	8	34	71
q → k	1	0	0	0	0	0	1
q → g	26	17	14	8	4	1	70
q → b	1	0	0	0	0	0	1
q → d	0	4	0	0	0	0	4
q → h	1	0	0	0	0	0	1
q → p	1	0	0	0	0	0	1
q → x	0	0	1	0	0	0	1
q → ɛ	0	0	0	0	1	0	1
q → ɣ	8	7	7	4	0	0	26
q → ʃ	1	0	0	0	0	0	1
q → χ	0	2	0	0	0	0	2
[q] deletion	7	0	5	1	3	0	16
Percentage	8%	15%	32%	41%	58%	99%	36%

Pronouncing [g] instead of [q] was the most frequent type of “fronting” in corpora. Figure 3 demonstrates the acquisition curves of [k], [g] and [q] as the dorsal plosives. As it is discernable [q] was acquired remarkably later than [k] and [g].

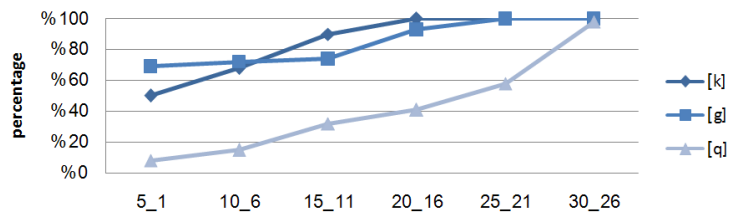


Figure 3. The acquisition curves of velar and uvular plosives

Nasals

Nasals were the least problematic consonants for the subjects to pronounce. [m] was pronounced properly 94% of the times the study’s subjects attempted. The number of omitted [m] was remarkable (7% of all attempted [m]) and was more frequent in onset position. Omission of [m] was not disappeared during theyear of study. In the beginning of the enquiry the subjects had an acceptable expression of [m] and it was accomplished around the age 3.4 in the thirteenth audio file. [m] was also considered as an acceptable articulation of [m].]. Similar to [m], [n] had a proper pronunciation in the study’s commencement. The only difference was that the subjects gained its immaculate verbalization around the age of 3.9 in the twenty second file. Omission of [n] was observed frequently but it was diminished in three last files. [ŋ] was regarded acceptable for determining the amount of correct articulation of [n]. The following table depicts the subjects’ performance in [n] productions. Tables 8 and 9 show the subjects’ productions for [m] and [n] on average.

TABLE 8. VARIATIONS IN ARTICULATING [m]

Audio file	1-5	6-10	11-15	16-20	21-25	26-30	Total
Variations							
m → m	392	361	632	846	616	955	3802
m → m̥	5	1	9	0	0	0	15
m → b	2	1	0	0	0	0	3
m → h	2	0	0	0	0	0	2
m → j	0	0	1	1	0	0	2
m → n	2	2	0	0	0	0	4
m → s	1	0	0	0	0	0	1
[m] deletion	111	54	55	7	3	3	233
Percentage	74%	84%	92%	100%	100%	100%	94%

TABLE 9. VARIATIONS IN ARTICULATING [n]

Audio file	1-5	6-10	11-15	16-20	21-25	26-30	Total
Variations							
n → n	240	309	243	490	699	918	2899
n → ŋ	61	34	19	8	0	1	123
n → b	1	0	0	0	0	0	1
n → d	4	2	1	0	1	0	2
n → h	2	0	0	0	0	0	2
n → j	2	2	5	0	0	0	4
n → m	2	2	1	0	0	0	1
n → t	1	0	0	0	0	0	1
n → ɛ	1	1	0	0	0	0	2
n → dz	2	0	0	0	0	0	2
n → dʒ	0	1	0	0	0	0	1
[n] deletion	85	72	51	18	7	2	235
Percentage	74%	78%	80%	96%	99%	100%	94%

Figure 4 depicts the acquisition of [m] and [n]. Nasal productions of the subjects were quite acceptable, even better than plosives. Interesting point was the high frequency of nasal omissions particularly in onset position what was also proposed by Gordon (1995). Another interesting point was the difference in rates of [m] and [n] acquisition; [m] was acquired by far faster than [n]. Figure 4 schematized the acquisition curves of nasals.

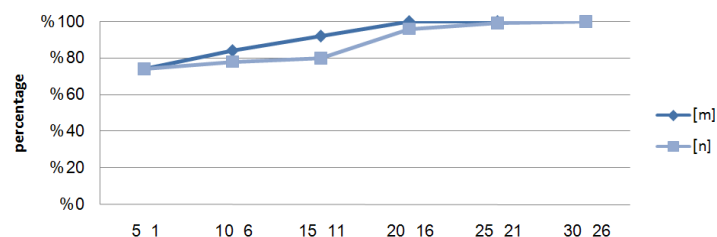


Figure 4. The acquisition curves of [m] and [n]

Trill

[r] is the sole trill consonant in Farsi for which the subjects' productions were interestingly poor; Only 17% of attempted [r]s were pronounced properly while [ɾ] was also reckoned as the acceptable articulation of [r]. It was replaced with [j] very frequently (approximately 60%) and not accomplished before the age of 4 during the study. [r] had also the second highest frequency of omission (21% of total [r]s were omitted) and this was not ceased until the end of observation. Table 10 displays the subjects' productions for [r] on average.

TABLE 9.
VARIATIONS IN ARTICULATING [r]

Audio file	1-5	6-10	11-15	16-20	21-25	26-30	Total
Variations							
r → r	6	3	8	6	35	26	84
r → ɾ	30	80	61	58	17	2	248
r → d	22	1	0	1	0	0	24
r → j	306	252	265	135	153	79	1190
r → l	1	0	0	0	1	2	4
r → m	2	1	0	0	0	0	3
r → n	4	0	0	0	0	0	4
r → d̪	1	0	0	0	0	0	1
r → t	1	0	0	0	0	0	1
r → w	2	0	0	0	1	0	3
r → ʃ	1	0	0	0	0	0	1
r → ʒ	0	0	0	0	1	0	1
r → y	0	0	1	0	0	0	1
r → z̪	0	1	0	0	0	0	1
r → z	2	0	0	0	0	0	2
[r] deletion	175	125	68	27	17	10	422
Percentage	6%	17%	19%	27%	21%	33%	17%

Figure 5 depicts the subjects' acquisition curve of [r] although it was not completed before the age four.

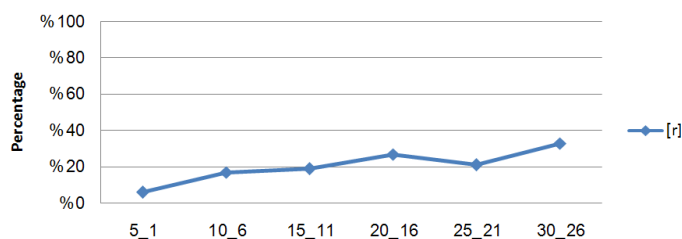


Figure 5. The acquisition curve of [r]

Fricatives

*Labiodental fricatives*_ [f] was undoubtedly the easiest consonant for the subjects to pronounce. It was pronounced properly from the beginning of the study and accomplished earlier than other consonants at the age of 3.3 in the sixth audio file. 96% of attempted [f]s were articulated properly during the study and only 2% of total [f]s were omitted. In addition to [f], [v], [ɸ] and [v̥] was also considered as the acceptable pronunciation of [f]. Table 10 is the average performance of the subjects for [f] throughout thirty audio files.

TABLE 10.
VARIATIONS IN ARTICULATING [f]

Audio file	1-5	6-10	11-15	16-20	21-25	26-30	Total
Variations							
f → f	18	13	35	21	38	63	188
f → v	9	1	0	0	0	0	10
f → ɸ	1	1	2	0	0	0	12
f → v̥	0	1	0	0	0	0	1
f → ɛ	1	0	0	0	0	0	1
f → ʃ	0	1	0	0	0	0	1
[f] deletion	2	0	1	0	0	0	3
Percentage	93%	97%	100%	100%	100%	100%	96%

Consonant [v] had also an acceptable articulation from the beginning of the enquiry but it was not as unchallenging as [f]; only 90% of total tried [v] had acceptable pronunciations and only 3% of [v]s were omitted. [f] was also assumed as the acceptable articulation of [v] due to the common place of articulation. Replacement of [v] for [f] was more frequent than replacement of [f] for [v] (6% versus 3%). [v] pronunciation became perfect around the age of 3.8 in the nineteenth file. Table 11 shows the productions of the subjects for [v] which has more variations than [f].

TABLE 11.
VARIATIONS IN ARTICULATING [v]

Audio file	1-5	6-10	11-15	16-20	21-25	26-30	Total
Variations							
v → f	22	20	14	21	66	64	207
v → v	0	1	2	2	3	0	8
v → b	1	2	0	0	0	0	3
v → d	1	0	0	0	0	0	1
v → m	0	2	0	0	0	0	2
v → w	6	0	0	0	1	0	7
v → ʃ	0	0	0	0	0	1	1
[v] deletion	1	4	2	1	0	0	7
Percentage	67%	73%	89%	96%	100%	100%	90%

Figure 6 illustrates the acquisition curves for labiodentals fricatives during the year of inspection.

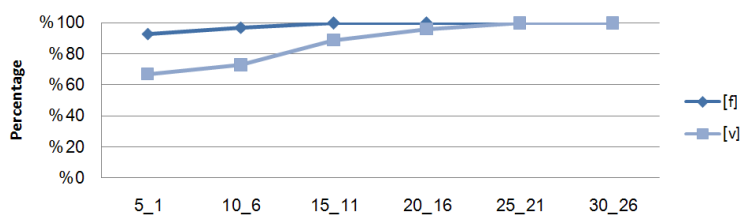


Figure 6. The acquisition curves of [f] and [v]

(Post) alveolar fricatives_ Among these consonants only [ʒ] had an acceptable pronunciation in the beginning. Production of [s] was very poor in the beginning of the observation (the average of correct articulation of [s] in the first five audio files was less than 11%), but subjects showed good rates of [s] acquisition that its production was accomplished before the age of four in the twenty third audio file. 53% of total [s] productions were acceptable while many variations were observed for [s] enunciations. Due to the same place of articulations [z] was also considered as the approved pronunciation of [s]. Table 12 shows the subjects' variations for [s] on average.

TABLE 12.
VARIATIONS IN ARTICULATING [s]

Audio file	1-5	6-10	11-15	16-20	21-25	26-30	Total
Variations							
s → s	18	53	50	38	112	118	389
s → z	1	1	0	0	0	0	2
s → ɛ	95	54	29	20	3	2	223
s → ɕ	8	9	1	13	0	0	31
s → ʂ	4	0	16	0	0	0	20
s → ʐ	0	1	2	0	0	0	3
s → z	1	5	0	0	0	0	6
s → d	3	0	0	0	0	0	3
s → ð	5	0	0	0	0	0	5
s → j	0	3	0	0	0	0	3
s → t	7	1	2	0	1	0	11
s → ʃ	2	3	1	0	0	0	3
s → ʒ	11	3	0	0	0	0	14
s → ts	1	0	0	0	0	0	1
s → θ	26	3	2	0	0	0	31
[s] deletion	29	8	3	0	0	1	41
Percentage	11%	40%	48%	57%	95%	99%	53%

Production of [z] was more problematic than [s]; more than 55% of total [z]s were produced as retroflexed [ʐ] or [ʒ]. Only 23% of all attempted [z]s were pronounced properly and it was not accomplished despite the subjects' good rates of acquisition. [s] was judged to be appropriate production of [z]. Table 13 shows what the subjects produced for [z] during one year of enquiry.

TABLE 13.
VARIATIONS IN ARTICULATING [z]

Audio file	1-5	6-10	11-15	16-20	21-25	26-30	Total
Variations							
z → z	5	10	7	17	26	60	125
z → s	13	5	0	1	0	1	20
z → ẓ	5	26	85	34	0	8	158
z → z	7	68	18	24	6	0	123
z → d	17	3	0	2	0	3	25
z → ð	0	12	6	0	0	0	18
z → j	2	1	0	0	0	0	3
z → t	3	0	0	0	0	0	3
z → ɛ	1	2	0	0	1	0	4
z → d̪	1	0	0	0	0	0	1
z → f	2	0	0	0	0	0	2
z → ʒ	31	16	0	0	0	0	47
z → dʒ	1	1	0	0	0	0	2
z → dʒ	0	1	0	0	0	0	1
[z] deletion	2	7	1	0	0	0	10
Percentage	11%	4%	5%	23%	79%	77%	23%

[ʒ] as a post-alveolar fricative articulation was perfect from the very beginning of the study unlike to [ʃ] which was one of the most challenging consonant for the subjects. Only 8% of all tried [ʃ]s were acceptable; 32% and 50% of total [ʃ]s and were pronounced [s] and [ɛ] respectively. [ʃ] accomplishment did not happen before the age of four but its acquisition was perceptible during the year of observation. Due to the common place of articulation [ʒ] was assumed to be the proper articulation of [ʃ]. Table 14 shows what was produced for [ʃ] by the subjects on average.

TABLE 14.
VARIATIONS IN ARTICULATING [ʃ]

Audio file	1-5	6-10	11-15	16-20	21-25	26-30	Total
Variations							
ʃ → ʃ	6	4	8	6	10	25	59
ʃ → ʒ	10	8	0	0	1	0	19
ʃ → s	56	71	24	14	64	70	299
ʃ → ɛ	159	103	103	63	30	5	463
ʃ → ʂ	1	0	4	3	1	0	9
ʃ → ɟ	1	3	0	0	0	0	4
ʃ → d	2	1	0	0	0	0	3
ʃ → g	1	0	0	0	0	0	1
ʃ → h	1	0	0	0	0	0	1
ʃ → n	1	0	0	0	0	0	1
ʃ → t	7	2	3	0	0	1	13
ʃ → z	0	1	0	0	0	1	2
ʃ → ẓ	0	2	0	0	0	0	2
ʃ → z	1	3	0	0	0	0	4
ʃ → ts	1	1	0	0	0	0	2
ʃ → tʃ	1	0	0	1	0	0	2
ʃ → θ	11	5	1	0	0	0	12
[ʃ] deletion	10	5	5	1	2	7	29
Percentage	6%	6%	6%	7%	10%	23%	8%

Figure 7 illustrates the acquisition curves of [ʃ], [s] and [z]. As it is discernable the productions of all these consonants were poor at the age of three and [s] was the only alveolar fricative which was accomplished before the age of four.

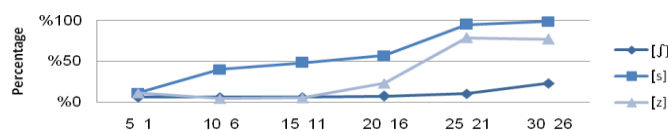


Figure 7. The acquisition curves of (post) alveolar fricatives

*Velar fricative*_ Articulation of [x] as the only velar fricative in Farsi was reasonably good from the beginning of the enquiry. 94% of all attempted [x]s were pronounced properly and it was accomplished around the age of 3.5 in the thirteenth audio file. Production of [ɣ] and [χ] were judged as the good pronunciation of [x]. Table 15 shows the subjects' performance for [x].

TABLE 15.
VARIATIONS IN ARTICULATING [x]

Audio file	1-5	6-10	11-15	16-20	21-25	26-30	Total
Variations							
x → x	8	32	31	91	81	150	393
x → y	46	20	14	8	5	1	94
x → z	132	115	35	12	0	3	297
x → g	4	0	0	0	0	0	4
x → h	31	2	1	0	0	0	34
x → k	2	0	0	0	0	0	2
[x] deletion	5	5	2	0	0	1	13
Percentage	81%	96%	95%	100%	100%	100%	94%

As Figure 8 depicts the study's subjects had good productions [x] between the ages of three and four.

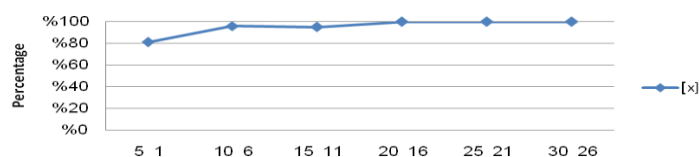


Figure 8. The acquisition curve [x]

Glottal fricative_ Articulation of [h] was good from the beginning. The only noticeable problem was h-deletion. It was the most omitted consonant; 37% of all endeavored [h]s were omitted and it was not stopped until the end of the observation. Neglecting h-dropping, [h] was accomplished in the nineteenth audio file around the age of 3.8. The following table presents productions of the subjects for [h] considering h-dropping as a cause of [h] failure and Figure 9 demonstrates acquisition curve of [h].

TABLE 16.
VARIATIONS IN ARTICULATING [h]

Audio file	1-5	6-10	11-15	16-20	21-25	26-30	Total
Variations							
h → h	27	24	41	34	77	136	339
h → g	0	0	0	1	0	0	1
h → j	2	0	0	1	0	0	3
[h] deletion	70	33	35	24	22	11	195
Percentage	28%	42%	54%	58%	78%	92%	63%

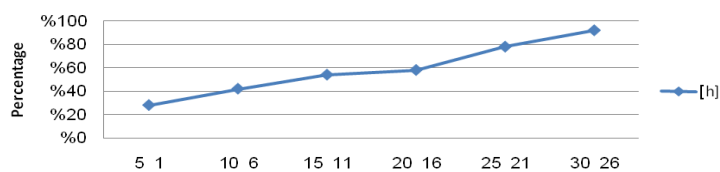


Figure 9. The acquisition curve [h]

Affricates

[dʒ] and [tʃ] are two Farsi's affricates. Performance of the subjects for producing these two consonants was remarkably poor. Affricate-omissions were not frequent implying that despite difficulty in articulation; the study's subjects did not try to omit the affricates. Only 23% of total endeavored [dʒ]s were pronounced satisfactorily and 47% of [dʒ]s were replaced by alveolar plosive [d]. Articulation of [dʒ] improved during the year of observation but never accomplished. [ʒ] was also perceived as the acceptable pronunciation of [dʒ]. Table 17 shows what the subjects produced for [dʒ] on average.

TABLE 17.
VARIATIONS IN ARTICULATING [dʒ]

Audio file	1-5	6-10	11-15	16-20	21-25	26-30	Total
Variations							
dʒ → dʒ	3	4	3	29	27	17	83
dʒ → ʒ	6	2	0	0	2	0	10
dʒ → ð	1	0	0	0	0	0	1
dʒ → d	87	43	20	10	23	18	201
dʒ → j	2	0	0	0	1	0	3
dʒ → n	8	1	0	0	0	0	9
dʒ → s	1	0	0	0	0	1	2
dʒ → t	1	0	0	1	0	0	2
dʒ → z	1	6	0	1	0	0	2
dʒ → ɛ	2	0	0	0	0	0	2
dʒ → z	1	0	0	3	0	0	4
dʒ → dz	14	20	10	7	0	0	41
dʒ → dʒ	6	11	9	0	0	0	26
dʒ → tʃ	1	0	0	3	0	0	4
[dʒ] deletion	6	3	0	0	0	0	9
Percentage	6%	7%	7%	54%	55%	49%	23%

Production of [tʃ] was not as awkward as [dʒ] but it was also underprivileged. The subjects was successful only 45% of times. Like [dʒ], [tʃ] omission stopped around the age of 3.4 but its steady perfect articulation was not observed. 32% of all [tʃ]s were pronounced [t]. [tʃ] was judged as the proper enunciation of [tʃ] in the analysis. Table 18 depicts variations in pronouncing [tʃ] by the subjects on average.

TABLE 18.
VARIATIONS IN ARTICULATING [tʃ]

Audio file	1-5	6-10	11-15	16-20	21-25	26-30	Total
Variations							
tʃ → tʃ	7	6	7	4	22	21	83
tʃ → ʃ	2	3	1	0	2	0	10
tʃ → ɟ	0	1	0	0	0	0	1
tʃ → d	1	0	0	0	0	0	201
tʃ → s	9	4	1	0	0	1	3
tʃ → t	55	15	13	5	1	2	9
tʃ → ɛ	5	5	1	0	0	0	2
tʃ → dz	1	0	0	0	0	0	41
tʃ → dʒ	1	0	0	0	0	0	4
tʃ → dz	1	0	0	0	0	0	26
tʃ → ts	32	14	18	15	4	1	4
[tʃ] deletion	2	0	1	0	1	0	9
Percentage	8%	19%	17%	17%	80%	84%	45%

Figure 10 demonstrates the quality of affricate acquisition for the study's subjects.

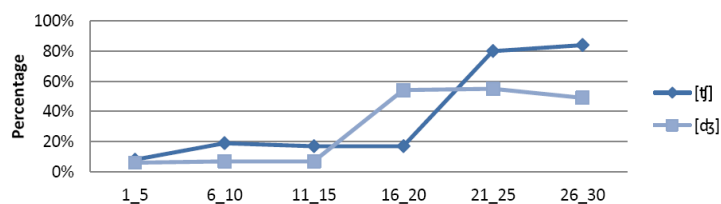


Figure 10. The acquisition curves [dʒ] and [tʃ]

Approximants

Among the approximants [w] was pronounced perfectly from the beginning but the story was different for [l]; 82% of endeavored [l]s were produced properly and its perfection happened around the age of 3.9 in the twenty second file. Production of [l] was also assumed as the acceptable articulations of [l]. Generally, articulations of [j] were better than [l] although the subjects' productions of [l] was better in the beginning; [j]'s perfect pronunciation observed sooner than [l] in the eighteenth file while 87% of all tried [j] were judged to be appropriate. Tables 19 and 20 present what was observed for [l] and [j], respectively. Figure 11 shows how approximants are acquired during the year of observation by the subjects.

TABLE 19.
VARIATIONS IN ARTICULATING [l]

Audio file	1-5	6-10	11-15	16-20	21-25	26-30	Total
Variations							
l → l	57	84	89	73	118	186	607
l → ɫ	52	12	8	3	2	3	80
l → d	0	0	1	1	0	0	2
l → h	1	0	0	0	0	0	1
l → j	31	18	11	4	4	2	70
l → n	4	1	0	0	0	0	5
l → t	1	0	0	1	0	0	2
l → ʎ	1	0	0	0	0	0	1
l → ɾ	1	1	1	0	0	0	3
[l] deletion	29	17	5	11	6	1	69
Percentage	62%	85%	84%	84%	92%	98%	82%

TABLE 20.
VARIATIONS IN ARTICULATING [j]

Audio file	1-5	6-10	11-15	16-20	21-25	26-30	Total
Variations							
j → j	52	29	98	75	75	167	496
j → d	2	0	1	0	0	0	3
j → h	0	0	0	1	0	0	1
j → l	1	1	1	0	0	0	3
j → s	1	0	0	0	0	0	1
j → ʒ	1	0	1	0	0	0	2
j → dʒ	0	1	0	0	0	0	1
[j] deletion	31	17	13	5	4	0	70
Percentage	59%	60%	87%	93%	95%	100%	87%

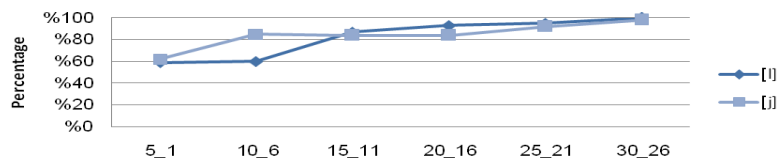


Figure 11. The acquisition curves [l] and [j]

As it is implied through the previous sections articulations of all the consonants (with no exceptions) improved and omissions diminished as the time passed. As the following table illustrates, in the beginning, nasals, approximants and plosives were the best articulated consonants and accomplished at the end of observation. Articulations of fricatives were meaningfully weaker and have not been idealized at the age of four. Productions of affricates were amazingly poor in the initiation however their rates of acquisition were surprising. [r] had the lowest rate of acquisition and remained the most problematic consonant at the age of four. Figure 12 presents a general view of acquisition on the basis of consonantal categories.

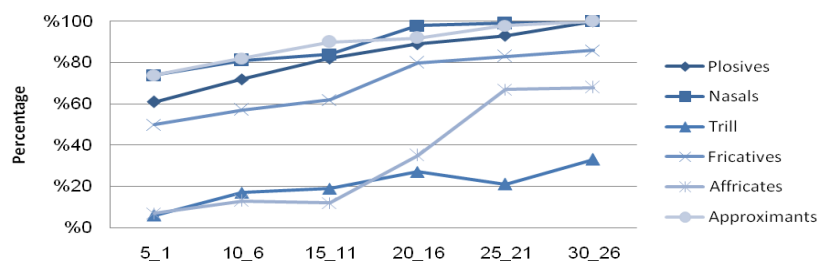


Figure 12. The consonantal categories' acquisition curves

V. CONCLUSION

This study was aimed at determining the developmental changes of Iranian children between the ages of three and four for all Farsi's consonants' articulations. The following table is the report of repeated measure analysis (a statistical mean comparison technique) which summarizes the findings of the study. The meaningful improvements of consonants' articulation of the subject for consequent periods of time are shown by “*”. As it is discernable, only two consonants of [w] and [ʒ] had been accomplished before the observation initiated. [f] was accomplished before the fortieth month; [m] and [x] found their perfect enunciation in the forty second month while the pronunciation of the other bilabial fricative [v] was idealized later in the forty fourth month along with [b], [d], [h] and [g]. [t], [n] and two approximants were

perfectly produced in the forty sixth month and [s] got its steady idealized pronunciation at the end of study in the forty eighth month. [r] in addition to affricates and two fricatives of [z] and [ʃ] were in the process of completion when the inquiry terminated. Eight consonants from a total of twenty three found their idealized articulations between the forty third and forty sixth month of the subjects' age. This implies that these four months can be assumed as the peak of Farsi consonant acquisition.

TABLE 21.
THE ACQUISITION TIMELINE FOR ALL CONSONANTS OF FARSI

Consonantal category	Audio files Consonant	Months	1-5	6-10	11-15	16-20	21-25	26-30
			37/38	39/40	41/42	43/44	45/46	47/48
Bilabial plosive	[b]	Before the study (0 to 36 month of age)	0.676	0.341	0.126	0.048*	0.014*	0.001*
Bilabial plosive	[p]		0.314	0.118	0.043*	0.023*	0.011*	0.001*
Alveolar plosive	[t]		1.118	0.986	0.075	0.056	0.049*	0.002*
Alveolar plosive	[d]		3.124	1.897	0.836	0.048*	0.031*	0.001*
Velar plosive	[k]		1.654	1.119	0.042*	0.032*	0.011*	0.000*
Velar plosive	[g]		0.763	0.435	0.052	0.031*	0.015*	0.000*
Uvular plosive	[q]		2.786	2.156	1.345	0.076	0.056	0.049*
Nasal	[m]		0.074	0.053	0.043*	0.012*	0.000*	0.000*
Nasal	[n]		3.897	3.123	2.127	1.342	0.048*	0.012*
Trill	[r]		4.378	3.746	2.243	1.567	0.0654	0.038*
Bilabial fricative	[f]		0.074	0.021*	0.014	0.000*	0.000*	0.000*
Bilabial fricative	[v]		1.768	0.987	0.534	0.033*	0.001*	0.000*
(Post)alveolar fricative	[s]		5.464	5.123	3.908	2.567	0.0876	0.011*
(Post)alveolar fricative	[z]		3.768	3.123	1.897	1.112	0.0768	0.019*
(Post) alveolar fricative	[ʃ]		2.345	2.004	1.980	0.076	0.086	0.009*
(Post) alveolar fricative	[ʒ]		4.345	3.897	2.897	1.768	1.894	0.098
Velar fricative	[x]		0.765	0.560	0.041*	0.018*	0.000*	0.000*
Glottal fricative	[h]		0.876	0.543	0.054	0.038*	0.002*	0.000*
Affricate	[dʒ]		4.324	2.987	1.987	0.876	0.076	0.029*
Affricate	[tʃ]		4.879	3.786	1.678	0.098	0.076	0.041*
Approximant	[w]		4.678	4.231	3.903	1.765	0.098	0.087
Approximant	[l]		1.980	0.098	0.065	0.053	0.037*	0.000*
Approximant	[j]		1.786	0.986	0.876	0.075	0.008*	0.000

Although studies of consonant acquisition date back to more than a hundred years ago, the progress in this field has been very slow (Pater & Werle, 2003). Moreover, more detailed studies are necessary to have empirically defensible answers to the related questions such as: “how consonants are acquired in different languages?”, “Are the consonants' acquisition processes universal or language-dependent?” and “Do consonants and vowels follow a similar order of acquisition?”

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