AN INVESTIGATION ON THE VALUE OF INTERVALS IN PERSIAN MUSIC

Farshad Sanati

Master's Thesis

Music, Mind and Technology

Department of Music

27 July 2020

University of Jyväskylä

JYVÄSKYLÄN YLIOPISTO

Tiedekunta – Faculty Humanities	Laitos – Department Music Department
Tekijä – Author Farshad Sanati	
Työn nimi – Title An investigation on the value of intervals in Persian music	
Oppiaine – Subject Music, Mind & Technology	Työn laji – Level Master's Thesis
Aika – Month and year July 2020	Sivumäärä – Number of pages 42
Tiivistelmä – Abstract Theory of intervals in Persian music has a history of over 1000 years. Two influential theories regarding interval sizes have been proposed during the 20th century, first one by Ali Naqi Vaziri at the beginning of 20th century (1913) and the second one by Daryoush Talai at the end of 20th century (1995), but still the exact size of intervals is a matter of discussion between Persian musicians and theoreticians. This thesis investigates the possible similarities between the interval sizes found in theories and those used by Ney (Iranian classical flute) Players. The experiment stimuli are played by six Ney players which are categorized in 2 different groups, old and new generation. Players played pieces in all four main tetrachords in Persian music, namely *Shur, Chahargah, Dashti and Mahoor*. Exact amounts of pitches of each tetrachord were extracted using MIRtoolbox (an integrated set of functions written in Matlab); next size of intervals was calculated and compared with both theories. The analysis has shown that intervals played by the old generation are more correlated with old theory, while the new generation played intervals more correlated with the new theory. This study presents an interdisciplinary project involving musicology, ethnomusicology and music information retrieval. Most of the research in music information retrieval has been done on western classical music and working with non-western music is still an exploratory task and there is a great potential for future work in this domain.	
Asiasanat – Keywords Persian music, Tetrachord, Music Information Retrieval. Mirtoolbox, *Dastgah* System, content-based music analysis	
Säilytyspaikka – Depository	
Muita tietoja – Additional information	

ACKNOWLEDGEMENTS

I would like to thank Dr. Marc Thompson for giving me the chance to study this program through which I had a rich academic experience, and also for being very flexible towards my studies.

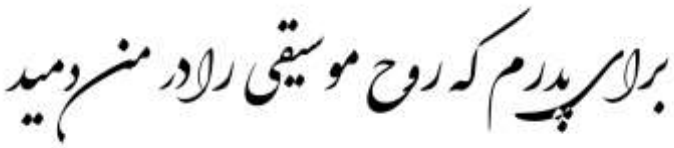
I would like to thank my dear supervisor Dr. Pekka Toivanen who manifolded the joy of studying this program by providing all possibilities to cooperate. I am also very grateful for his supports in all manners.

I thank my supervisor Dr. Martin Hartmann for his helpful guidance.

I like to thank Sahar, since without her it would not be possible to accomplish this work.

I thank Sheida, for her online motivative influence on me, and thank my mother, whose sense of presence from thousands of kilometers away, gives me confidence and peace.

And Finally, thanks to my father, who infused my life with the spirit of music.



CONTENTS

1 INTRODUCTION

Most of the topics of research in the field of music and music technology and music information retrieval and other music related research domains are about western classical and pop music. During the last few decades, other kinds of world music like Indian, Turkish and Arabic musical cultures have also been studied to some extent. While, Iranian music that is one of the most important music systems in the Middle East, and many other musical cultures like Turkish, Azeri and Arabic have roots in it, has remained highly unknown, as very limited number of researches have been done about it. The goal of this paper is to take a step for compensating this negligence and make more people familiar with Persian music and its theory and potentials.

Working with ethnic music is problematic in different cases. First is that there is not any standard theory for these musical cultures. As the second reason it can be mentioned that working with ethnic music needs new approaches compared to western music, because you have to work with a vast group of music, cultures and theories which are completely different from predefined western standards (Colrnelis, et al, 2008).

Pitch concept is one of the elements which is completely different in non-western music compared to western one. Historically we can say that in contrast to western classical music, which is based on tonal music (tonal center and harmony have significant roles), we have a modal system in Asia and Middle East**.** *Maqam* system in Turkey, Maqam system in Arabic music, and *Dastgah* in Persian music and Raga in India are more based on melody, while Pathet in Java and Choshi in Japan are more according to specific scale (Powers, 2008). Pitch Analysis has been an important topic in the music information retrieval field, also more important in computational ethnomusicology. Analyzing pitches in different ethnic music cultures shows that the western concept of pitch (standard twelve Western pitch classes) is too restricted or even meaningless in many other non-western music cultures, because music does not always consist of discrete pitch categories (Cornelis et al., 2009) For example classical Chinese music consists sliding pattern tones (pitch modulation) (Li, 2007), singers in Flamenco music slide pitches and use vibrato a lot in their music (Gomez and Banada, 2008), and musical cultures like Central-African and Indonesian consist a pentatonic structure but with many different measurements in different places. *Maqam* and *Dastgah* system in Middle-Eastern musical

cultures are also good examples. Arabic music uses a Twenty-four Equal quarter tones scale (Touma, 1996), in Turkish music each interval is Divided into 9 commas (Ederer, 2011) and Persian music has intervals like 80, 120, 140, 220 and 220 cents (Talai, 1993). There have been different interval structures in different musical cultures, while these structures have changed many times throughout history. Despite all ambiguities and unanswered questions about the history of music, there is one obvious fact that during thousands of years, millions of people have used music for expressing their feelings, whether happiness or sadness, without having a twelve-tone equal temperament system.

According to the facts mentioned above, research on frequencies and pitches in different ethnical music cultures, is a very difficult task, and software, methods and algorithms that are defined based on western classical music are not useful for it. There are several problems in using applications and software for ethnic and world music that are originally developed for western music. First problem is due to different pitch spaces in western music and other music cultures like Asian, African, Indian and Middle Eastern. Second one is the lack of music theory for ethnic and non-western music. (Moelants et al., 2006, 2007)

Following the goal to develop software, applications and technologies for non-western music, the Music Technology Group of Pompeu Fabra university in Barcelona in association with European Research Council, conducted a research project called Comp Music, started in 2011 till 2017, having Xavier Serra as the coordinator. The project was carry out in relation with music information processing, in which the focus area was five traditional musical cultures of different parts of the world, including Hindustani, the music of northern India, Carnatic, the music of southern India, Maqam, the traditional musical system of Turkey, Arab_ Andalusian, music of northern west Africa and Beijing Opera, the traditional music of China (https://compmusic.upf.edu/node/1). Software like Dunya desktop, which is a desktop application for accessing and visualizing music data like music scores, audio recordings, extracted features and analysis results. , Saraga an android application for Carnatic and Hindustani music, PycompMusic, Dynya browser, Turkish-Ottoman Maqam Music Analysis Toolbox which is toolbox for the analysis of audio recordings and music scores of Turkish-Ottoman *Maqam* music, Mode Recognition and Tonic identification for “modal” music cultures and some other applications and software.

During the last two decades some research has been done on computational ethnomusicology with concentration on Persian music. Darabi, et al (2006), did a research by the title of "recognition of *Dastgah* and *Maqam* for Persian music with detecting skeletal melodic models", in which the application of the pattern recognition techniques in identifying *Dastgah-s* and Maqam-s in Iranian music, considering musical modes, is examined. They focus on a *Dastgah* named Homayoon and the theory of dividing each octave into 60 intervals. In 2011 Abdoli in his article "Iranian traditional music *Dastgah* classification", talked about the description of *Dastgah-s* in Iranian music compared to its equivalents in other musical cultures, like western classical music and Turkish music, and proposed a *Dastgah* recognition system which can recognize the modes with overall accuracy of 85%. Heydarian (2016) in his study "Automatic recognition of Persian musical modes in audio musical signals", tries to propose a new perspective on computational identification of Persian *Dastgah-s*. His research is based on Vaziri's theory (24-TET) about the intervals in Persian music and he also categorized Persian modes in five main scales *(Esfehan, Chahargah, Shur, Mahoor, Segah*). finally "Classification of Iranian classical musical modes (*Dastgah*) with artificial neural network", compiled by Beigzadeh (2016), is an study in which the researcher aims to combine a basic knowledge on Iranian traditional music with mathematics, in order to use artificial intelligence in categorizing different modes of Iranian traditional musical modes, *Dastgah-s*. For doing it he categorizes the Iranian pieces of music and distinguishes their corresponding *Dastgah-s* by an accuracy rate of 55 to 75 percent according to their frequency spectrum and with the aid of the Fast Fourier Transform.

The current study investigates relationships between the pitches and intervals of four main tetrachords (*Shur, Chahargah, Dashti and Mahoor)* and two main theories about them by Vaziri (1913) and Talai (1995) in Persian music.

2 PERSIAN MUSIC

2.1 Terminology

2.1.1 Dastgah

Dastgah is defined as a multimodal cycle that starts with a mother *Maqam* and after it has employed all capacities of this basic *Maqam*, it uses other *Maqams* to continue the musical process, but every time it goes back to the basic *Maqams* to keep the general unity of the structure. Persian music repertoire includes seven main *Dastgah* plus five subsidiary *Dastgah* which are called *Avaz*.

2.1.2 Radif

It is a collection of melodies that have been gathered together by different musicians during years and added to the Persian music repertory, so it is a collection of classical melodies from rural and ethnical music cultures.

2.1.3 Sori (♯)

A sign that denotes half sharp and was invented by Ali Naqi Vaziri for the first time at the beginning of 20th century.

2.1.4 Koron *(♭)*

A Sign that denotes half flat and was invented by Vaziri.

2.1.5 Dang

It is Persian equivalent of tetrachord, and it is the main element for Persian music structure.

2.1.6 Gushe

Persian music repertoire included several short pieces and melodies. Each of these short pieces is called a *Gusheh*. *Gusheh* in Persian means corner. The most famous instrumental *Radif* by Mirza Abdullah includes 250 *Gusheh-s*.

2.1.7 Shahed

In each *Dastgah* there is a tone which has a prominent role in the melodical structure. It means that the melody is developed based on this tone. It could be called the centre of gravity of the melodical structure.

2.2 Remarkable theorists on Persian music

2.2.1 Barbad

The earliest documentation of a mode set in Persian music is a set of seven modes titled Rāh-hā-ye Khosrawāni, (equivalent to "Royal Passages") which was attributed to Bārbad, the legendary musician at the court of King Khosraw Parviz who lived in sixth century, was one of the last king of Sasanian Empire and died few years before the time that the dynasty was collapsed by the Muslim conquest of Iran. It is noteworthy that the legend of Bārbad and his set of seven modes survived as a myth in the oral knowledge of Persian music for more than six hundred years to appear in a Persian musical text by Mohammad Nishāburi in the thirteenth century (Mohammadi, 2017). It is also mentioned by later writers and poets that his musical system in addition to seven khosravani included thirty secondary modes (Lahn), and three hundred and sixty melodies (Dastan). These numbers were based on the numbers of the days in a week, month and year in the Sasanian calendar (Farhat, 1990).

2.2.2 Abu Nasr Al-Farabi (d.950)

The whole body of theory of music in the world of Islam is founded based on the compilations of Farabi, who theorized scales, intervals, musical modes and different rhythms, as well as the structure of musical instruments, considering the features of music of Islamic lands. His theories

were according to the older Greek writings on music, to which he played a significant role to liven. There remained his great book about music, called Ketab al-Musiqi al-Kabir. The name he is famous for, Farabi, refers to the town in which he was born, Farab, that was itself located in the greater land, Khorasan (Farhat, 1990).

2.2.3 Safi-od-Din Ormavi (d.1294)

The most vastly followed and practiced theory on intervals, used for defining modes, in the whole middle east, is compiled by this great musicologist. in his books called Resale al-Sarafiyye and Keteb al-Advar, which is one the most prominent reference for the Iranian-Islamic music theory. he added a lot on the previous modal scheme introduced by Farabi and Avecenna. During the fourteenth and fifteenth centuries, Ormavi's version of the two sets of twelve primary modes and six secondary modes became the dominant modal system in Persian, Arabic, and Turkish musical texts (Farhat, 1990).

2.2.4 Abd-ol-Qader Maraqi (d.1435)

He could be called the last music theorist of Persian music before the modern time, because after him there were four centuries of black silence in Persian music during the period of Shiite ascendancy. by following Ormavi's theories, he wrote two books, Maqāsed-ol-Alhān and Jāme-ol-Alhān. he also translated Ketāb-ol-Advār Ormavi's most famous book into Persian and wrote an interpretation on that. He talked about scales, modes, and instruments in his books and introduced a system for musical notation (Farhat, 1990).

2.3 *Dastgah* System in Persian Music

Dastgah is defined as a multimodal cycle, a collection of some melodic models, which are organized in a cyclic pattern based on a modal foundation. It is used for the first time as a new title in the late eighteenth and early nineteenth centuries. (Asadi 2003, Mohammadi, 2017) The word *Dastgah* is used instead of *Maqam* in Iraninan music, most probably from the Qajar dynasty period forward (19th century). *Dastgah* is a combination of two words. "Dast" and "Gah". "Dast" in Persian means hand, and "Gah" in ancient Persian music referred to the position of the fingers on the neck of the instrument. Accordingly, "*Dastgah*" means the manner

of positioning hands (fingers) on the frets of the instrument, and these positions are different in each *Maqam* (Fakhreddini, 2015). *Avaz* -s assumed as subsidiary and derivative *Dastgah*, just with more simple modal structures (Asadi, 2003). *Dastgah* is a musical system starting with a mother *Maqam* and after it has employed all capacities of this basic *Maqam*, it uses other *Maqams* to continue the musical process, but every time it goes back to the basic *Maqam* to keep the general unity of the structure. In this regard, *Dastgah* is a set of melodies with the quality of being semi open and semi closed. Semi closed in the meaning that specific musical events will happen for sure in a specific *Dastgah*, and semi open in the meaning that the performer of the music has a kind of freedom in practically performing these events (Fayyaz, 2012). Iranian music is a galaxy of *Maqam*. From 200 years ago, Iranian aesthetic taste gradually tried to gather these small and big asteroids, connect them in united systems and put a *Maqam* like sun in the centre of each system. This *Maqam* is the mother *Maqam* or mother mode of the *Dastgah* that gets its name from it, just like the solar system.

2.3.1 Mother mode

Mother mode is usually a series of five-six notes, with a specific music interval pattern and a powerful gravitational field around the *shahed*. It means that all melodies in that mode tend to develop around this tone. The *Dastgah* system is one among many different systems of categorizing music in different musical cultures that is classifying collections of *Gusheh-s* based on their similarities. There is no absolute correct classification. All different classifications are relative. An efficient classification system not only gives order to the subjects and generalizes and unify the sporadic items, but also can be a bridge for new procreations. It was only one hundred and fifty years ago when Iranian music was categorized in seven *Dastgah* -s and five *Avaz* -s. The idea of categorizing Iranian music in *Dastgah* -s, not only lessened disorders and regulated music education system, but also supported the compilation kind of artistic system and a kind of logic for creating music. It means that although the very basic reason to have the *Dastgah* system was the requirement for classification, later, the *Dastgah* system went much further to lead to a logic for creation of music.

The historical taste of music in east as well as Iran, unlike in the west have had more tendency to monophonic music. There is no doubt that this taste has influenced the course of development and evolution of *Dastgah* -s leading to the current form. Since centuries ago, European musical system has attempted to find solutions for vertical expansion of music, beside the attention paid

to the possibilities for horizontal expansion. This way, novel musical structures have been created. Based on this idea in horizontal expansion, the melody has the most important role in making music while in vertical expansion, harmony has the main role. On the contrary, the eastern musical systems, including the Iranian one, focused exclusively on the horizontal expansion by which achieved different aesthetics. The *Dastgah* system was one of the solutions of Iranians for horizontal expansion of music in time, with the goal to construct an artistic musical system. Briefly, there is a reciprocal relation between *Dastgah* music system and monophonic music.

Iranian *Dastgah* music in recent two centuries has been categorized in seven *Dastgah* -s and five *Avaz* -s. Seven *Dastgah* -s are *Shur, Nava, Segah, Homayun, Chahargah, Mahoor* and *Rast Panjgah*. The *Avaz* -s are *Abu Ata, Bayate Tork, Afshari, Dashti*, and *Bayate Esfehan*.

2.4 Radif

The word "*Radif*" in Persian language means row or order. *Radif* is a collection of Iranian traditional melodies, gathered as different instrumental and vocal narratives and organized in special order in the form of different *Dastgah* -s and *Avaz* -s (kalantari, 2011). In the other word, *Radif* is a method for classifying Goushe-s, with the goal to make it easier to teach them by repeating (Fakhredinni, 2015). Nur Ali Borumand Iranian musician and *Radif* theorist explains, the *Radif* is the principal emblem and the heart of Persian music. He adds that compared to other ethnic music cultures having a repertoire like *Radif* is quite unique. Ella Zonis (1973) in her book, classical Persian that was one of the first English-language books about Persian music defined *Radif* as a collection of folk melodies. Most of these traditional melodies are derived from folk and popular sources and there is no clear clue about the origins of them (Nettl, 1987).

Before transforming from the *Maqam* system to the *Dastgah* system in Persian music, teaching Iranian music was by means of *Maqam-s*. Afterwards, *Goushes* were defined and located under seven *Dastgah-s* and some *Maqam*s were preserved in the form of some *Gusheh-s* (Fakhreddini, 2015). First steps towards separation from *Maqam* to the *Dastgah* system were probably taken in the Timurid era during the fourteenth and fifteenth centuries. [Hajarian, 2016] However, there are different opinions about how music was taught during this era. Raphael Georg Kiesewetter believes that *Radif* got formed during this time in order to teach the details of

Iranian music individually (Hajarian, 2016), and Bruno Nettl asserts that the background of *Radif* goes back to the eighteenth century (Nettl,1987). They relate the formation of *Radif* to the accelerating influences of western culture during the Qajar dynasty's ruling in Iran (Hajjarian, 1999, Nettl, 1987). According to Bruno Nettl, this formation is correlated with the Iranian nationalist movements in the twentieth century, and an example of Iranian's attempts for announcement of their independence from Turkish and Arabic music, despite all the mutual roots (Nettl, 1987). This is while Dariush Talai and Mohammad Reza Lotfi discuss that collection of Iranian melodies in the form and order of *Radif* has not started before the nineteenth century (Talai 1993, Lotfi, 2008). Dariush Talai claims that the main goal of *Radif* establishment was to compile an orderly collection of traditional melodies. They were not necessarily intending to give order to modals, and accordingly did not clarify the relation of *Radif* with modes, as the educational system of *Radif* does not include any precise theory (Talai, 1993).

Dr. Safvat (1969), believes, different music masters have gathered different melodies to use them as teaching materials to rehearse and play by students. However, it is not very likely to find any information about rehearsals and the musical content of them, there remained only some names, not applicable for referring. Considering the contemporary Iranian and Arabic music both in their artistic and folkloric forms, it makes more sense to result that each master has tried to collect a unique treasury of well-known melodies or their variations, that are categorized based on their modes.

This is while Hormoz Farhat believes that this transition from *Maqam* system to *Dastgah* was because of the downfall in proficiency of musicians in Safavid era (1501-1736), 16th and 17th centuries in a way that they were not able to compose innovatively in a specific *Maqam* or scale and consequently turned to combining different *Gusheh-s* of different *Maqam-s*. As a result, it became inevitable to teach these *Gusheh-s* separately and classify them in one *Dastgah* with no mutual scale.

To sum up, it seems that *Radif* is collected to compile an orderly collection of traditional melodies for educational purposes, probably under the influences of western culture. Although transformation of *Maqam* to *Radif* and *Dastgah* system took place gradually from the middle of Safavid dynasty, the word *Radif* has just been used in the late Qajar time and could not be found in older texts.

Although, some Iranian musicians see the *Radif* as manifestation of dynamism and coherence in Iranian music throughout the history, still some critics like Ann Lucas (2014), believe that *Radif* appeared just suddenly in the middle of nineteenth century, and is mostly reflecting the innovation of court musicians of Qajar court. While, from the history of music in earlier times it can clearly be concluded that composing music in the older Iran was based on Maqam-s, as it has been in Arabic and Turkish music (Lucas, 2014). Moreover, the fact that *Radif* made by the court musicians, indicates the problem that it could not represent the music of the whole of Iran comprehensively. As it is the country, in which different ethnical groups with different forms of music live (Lucas, 2014). According to this perspective, Iranian *Radif* music as a modern method of classification and music education, owes its success to the couple of incidents. The preliminary support of the Qajar government, social and economic transitions of the time that made it possible for the *Radif* music to be brought out of the court and performed among the public, and the new economic and technical opportunities that facilitate the recording and vast publication of the *Radif* music.

2.5 interval

2.5.1 Pythagorean intervals

In Pythagorean scale, all notes are made by the 3:2 ratio. Which is the ratio of a perfect fifth. Therefore, if we start from a note and move 6 times upwards and 5 times downward by the ratio of 3:2, the result will be all 12 notes in a Pythagorean scale.

Eb Bb F C G D **A** E B F# C# G#

This tuning system was prevalent during the Renaissance until the beginning of the 16th century. However, since the 18th century Twelve-tone equal temperament is the tuning system which is used mostly in western and classical music.

2.5.2 Western classical intervals

In western classical music, intervals are defined based on equal temperament theory. In this theory, each octave includes 1200 cents, and divided into 12 equal semitones. Therefore, each of these half steps are about 100 cents, and each whole interval will be about 200 cents.

Based on Pythagorean 12 notes theory two different semitones are:

- Diatonic semitones with the size 90 cents (e.g. between A AND Bb)
- Chromatic semitone with the size of 113 (e.g. between Bb and C)

While in12 equal tempered chromatic scales, all semitones have the same size, which is exactly 100 cents.

2.5.3 Intervals in middle eastern music culture

The tuning system for Advar (Middle-eastern music theory) structured based on Pythagorean tuning system, so each *Tanini* interval (whole interval) is about 203.91 cents or almost 204 cents instead of 200 cents, and each *Baghie* (half interval) is about 90 cents. Based on the middle eastern medieval music theory we had three different second intervals, *Tanini* (1 step), *Mojannab* (3/4 step) and *Baghie* (1/2 step). Ormavi believed that each octave includes 17 tunes, in which some intervals are microtones. For instance, a *Mojannab* interval is about 180 cents (Khazraie, 2018).

In Persian, Turkish and Arabic music cultures, which are microtonal music cultures, using the equal tempered tuning system has not been common before the twentieth century. The first idea for using 24 EDO, the quarter tone scale (or 24-TET), was brought up by Mikhail Mishaqa (Touma, 1996), Syrian musician. In Iranian music this idea was introduced by Ali Naqi Vaziri for Tuning Iranian Modes in 1920 (Farhat, 2004). In this tuning system, each octave divided into 24 equal pitches by 50 cents intervals.

During the Qajar era and transmission time from *Maqam* to *Dastgah* system, Vaziri introduced 24 EDO-s theory for Iranian music in 1920, which rejected later by most of the Persian music theorists like Barkeshli, Talaie, Kiani and Alizadeh. Based on Vaziri's theory a *Mojannab* (3/4) size is 150 cents, while Kiani's measurement resulted in 144 cents (Kiani, 2013) and Talai believes that it is 140 cents (Famourzadeh, 2005).

2.3.3.1 Advar system (Farabi, Ormavi, Maraqi)

This group of intervals all belong to the times before the modern era. Maraqi talked a lot about Safi al-Din Ormavi in his music theory and has followed Ormavi's gamut as the basic of his musical structure. He defined four different second intervals, which were introduced as the

fundamental intervals for making all tetrachords and pentachords and Maqam-s. These intervals are as categorized in Table 1 below (Maraqi, 1991):

TABLE 1. Intervals.

Name	Explanation	Size (cents)
Tanini	1 interval	204
Baghie	½ interval	90
Mojannabe Bozorg (big Mojannab)	One coma smaller than a Tanini	180-182
Mojannabe Kuchak(small Mojannab)	One coma bigger that Baghie	112-114

Based on this idea Ormavi's and Maraqi's theoretical Gamuts[1] will be as follow in Figure 1 and 2 (Khazrai, 2009):

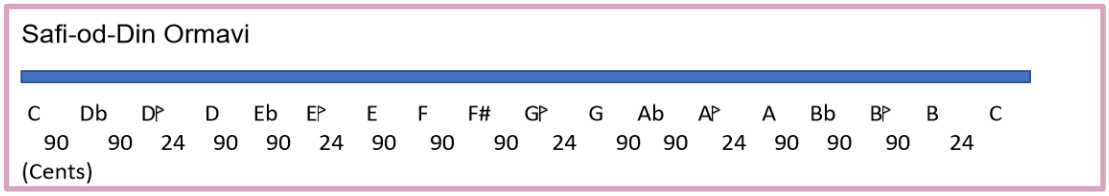


FIGURE 1. Gamuts by Safi-od-Din Ormavi.

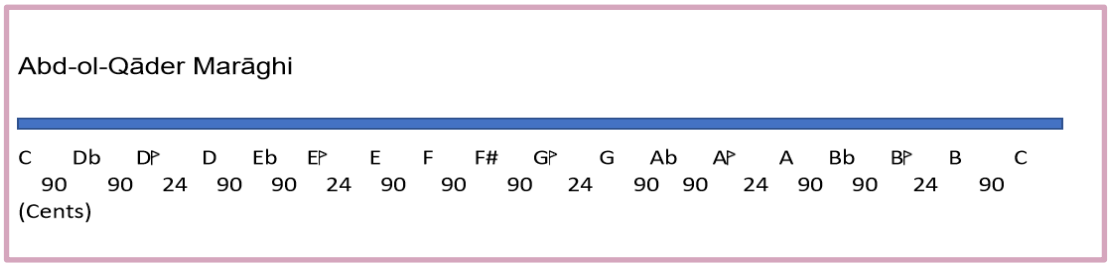


FIGURE 2. Gamuts by Abd-ol-Qader Maraghi.

The only difference is for the last two intervals.

2.3.3.2 Intervals in Persian music of 20th century

[1] . Theoretical gamut, is used for the first time by Owen Wright (1978, page 24),in studying the Ormavi's proposed modal system, Adwar, which means the scale that potentially exists in a musical culture and includes all the possible notes within an octave in that music culture

In Persian music, Despite the theoretical approach, interval is not an absolute unit, but a flexible amplitude. This flexibility is an important feature of Persian music language, which is leading to a modal music processing and personal performances. It is not obtained from special rules, but rather the musical atmosphere affects a lot it is creation and understanding. In Persian music melody is created by ascending or descending step by step in the scale (tetrachord or pentachord), so the second intervals are the most important. Based on Talai's studies (Talaie,1993) second intervals in Persian music have a range between 80 to 250 cents. It does not mean that the interval changes in this amplitude, but it can be different based on the mode (tetrachord), the doctrine and the personal style of the musician.

During the 20th century, 4 different theories on intervals and scales of Persian music have been proposed.

- **The 24-quarter-tone scale by Ali Naqi Vaziri in 1920s:** Theoretically, in a microtonal system the second intervals are as follows: half interval (1/2), three quarters of interval (3/4), one interval (4/4) and 5 quarters of interval (5/4). We can play the whole Persian music repertoire with this system. It was introduced for the first time by Ali Naqi Vaziri in the beginning of the 20th century. He put forward a 24-quarter-tone scale for Iranian music. The basic idea was taken from western 12 equal tempered scale and the 24 EDO by Mikhail Mishqa. This system was implemented in his musical college and most of the musical bands in radio and TV accepted and used it for decades. Although this system is easy to understand and practically efficient to be used for a band to play together, it demands a degree of negligence in accuracy of intervals, that most of the performers and soloists of Persian classical music will not accept.

Vaziri's theoretical gamut is shown in Figure 3 (Vaziri, 1913):

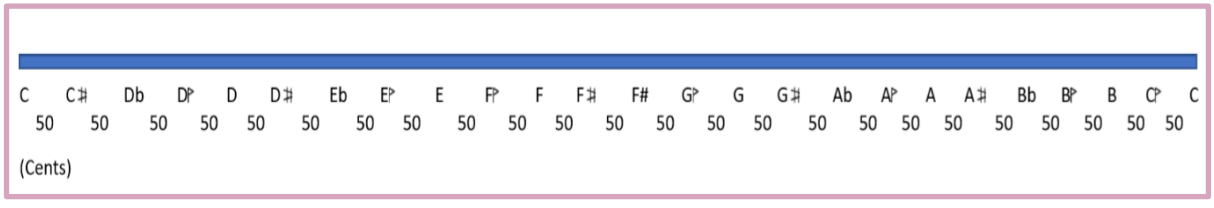


FIGURE 3. The 24-quarter-tone scale by Ali naqi Vaziri.

- **The 22-tone scale by Mehdi barkeshli:** Mehdi Berkeshli proposed his theory based on the medieval writers and music theorists like Abu-Nasr Farabi and Safiaddin Ormavi. In the tenth century (Farabi time), the Pythagorean intervals of limma and comma had become the basis of the intervals. Pythagorean comma (between two enharmonically equivalent notes) is about 24 cents and Pythagorean limma (Pythagorean diatonic semitone) is about 90 cents. Barkeshli concluded that the whole tone and semi- tone in Persian music are stable and closely duplicate the same intervals in the Pythagorean classification 204+206+89=499. These intervals are shown in Table 2.

TABLE 2. The intervals of 22-tone scale.

Interval	value
Lima	90
Lima+ Coma	120
Lima+ Lima	180
Lima+Lima+Coma	204

- **The flexible intervals by Hormoz Farhat:** By questioning the two last theories from Barkeshly and Vaziri, Hormoz Farhat (1971), put forward a new theory called the theory of flexible intervals. Like many other Iranian musicians, he also believed that the 24note EDO (Vaziri's theory) does not match the reality of Iranian music in practice. He also questioned this perspective that medieval music theories can be used in performing Iranian music. He believed that the authors who suggested these theories are mostly philosophers, theorists and encyclopedists, rather than music players or composers. And that not only, no instrument in middle - east is capable of playing such accurate intervals, but also the vocal music of this area is even less capable of doing this. Accordingly, Barkeshly's research on the intervals of Iranian music that are mainly done based on vocal music are not reliable. According to Farhat's theory, the basic structure of all *Maqam-s* and *dastgah*-s in Iranian traditional music are five different intervals, and it is useless to find a basic scale for this music. For the possibly most accurate measurement of these intervals, he used the Iranian instruments, Tar and Setar with fixed frets, and as technical tools, he used a stroboconn and a melograph.

Farhat's calculations showed that although length of whole interval and half interval in Iranian music is almost fixed, the concept of length here is a bit different with what it is in the tuning system of western music and is rather near to the interval in Pythagorean tuning. He calculated the length of interval in Iranian music to be about 204 cents and half interval to be 90 cents, and even sometimes as short as 80 cents. Farhat also found intervals with the size between interval and half interval. Finally, from his analysis, he came to this conclusion that tuning of Iranian instrument intervals matches much better with the 17 intervals scale of Safieddin Ormavi than the equal tempered (Farhat, 1971). He categorized all second intervals in Persian music in four different groups: Minor second, neutral tone (small and large), major second and plus-tone, that is shown in Table 3.

TABLE 3. Second intervals by Farhat.

Interval	Symbol	Size	Size (Cent)
Semitone or minor second	M	½ interval	90
Small neutral tone	N	¾ interval	130-135
Large neutral tone	N	¾ interval	160-165
Whole tone or Major second	M	4/4 interval	204
Plus-tone	P	5/4 interval	270

Based on his idea his Theoretical Gamut will be as follows in Figure 4 (Farhat, 1990).

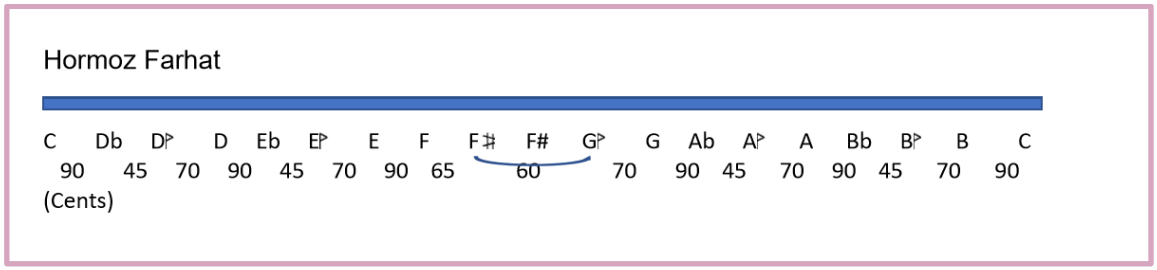


FIGURE 4. Theoretical Gamut by Farhat.

- **Contemporary theories by Talai:** Despite the wide range of flexibility and fluctuation in musical intervals, theoretically all the possible second intervals belong to one of these four groups (Khaleghi, 2007, Talai, 2015). This theory is almost similar with Farhat theory and there are only some differences between the sizes in cent that are categorized in Table 4.

TABLE 4. Intervals based on contemporary theories.

Interval (Talai's name)	Old books names	Symbol	size	Size (cent) (Talai, 2015)
Kuchak (Small)	Tanini	T	½ interval	80-120
Khonsa (neutral)	Baghieh	B	¾ interval	140-150
Bozorg (big)	Mojannab	M	1 interval	180-220
Bish bozorg (over big)	Bish-Tanini	BT	5/4 interval	240

The important point about these intervals is that they get different amounts in different tetrachords, which will be explained more in the Persian tetrachord sub chapter. Talai's theoretical gamut will be as follow in Figure 5 (Talai, 1995):

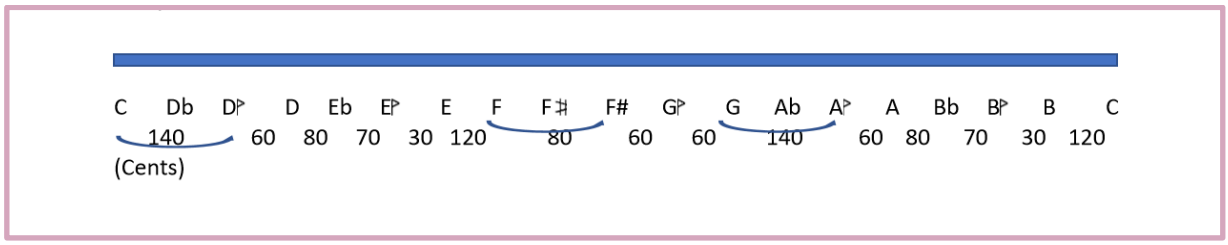


FIGURE 5. Theoretical Gamut by Talai.

At the end, it should be mentioned that interval is not an absolute concept, and different cultures have different criteria and taste for that. One interval could be considered consonant while it looks dissonance in another culture. Some intervals like perfect fifth and fourth known consonants almost in all cultures.

2.6 Persian music structure

2.6.1 Octave scale for Persian music

In this theory an octave (scale) is introduced as the unit of melodic structure for Persian music. In this point of view, the role of each note in the scale is defined based on the role of the scale degrees in classical western music. Ali Naqi Vaziri and his students explained Persian music scales by this method. For example, in figure 6 we can see the *Shur* scale based on Vaziri's idea.

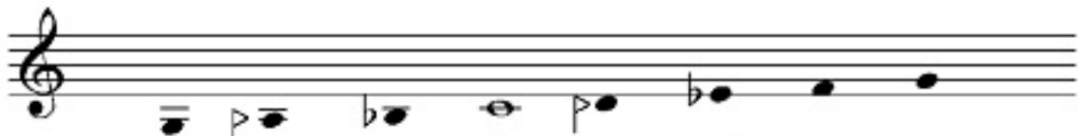


FIGURE 6. *Shur* scale

Vaziri redefined Iranian music, taking the European music of nineteen and eighteen centuries as a pattern. The music that is mainly defined in the span of one scale. And he intended to compromise Iranian music with the rules of tonic and under authority of tonic with the seven tunes. Accordingly, in the span of tetrachords and pentachords, he reduced the *Dastgah* system of Iranian music from the original twelve *Dastgah* to only five. It means there remained only *Shour, Mahour, Segah, Chahargah* and Homayoun and skipped *Rastpanjgah,* Nava, and the *Avaz* es, *Dashti, Bayate Esfahan, Afshari, Bayate Tork* and *Abouata*.

Since the publication of Vaziri's ideas, particularly in the last decades, his theory has been reviewed many times by different theorists and in many cases has been indicated on its inaccuracy. Goal of these critics has been to reveal the discordance of this theory with reality of the Iranian music in performance (Darvishi, 1994. Asadi, 2006). However, one will accept that Vaziri's *Dastgah* system music has vastly influenced the quality of Iranian music existence, in about one hundred years, since the establishment of this doctrine, a considerable part of Iranian music has been founded based on Vaziri's theories, directly or indirectly. After few hundred years of silence in theoretical work on Iranian music, he is the first authoritative musician who compiled theory in the field of Iranian music. Of his most important theoretical works, is making changes and manifesting new points of view in the system of intervals in

Iranian music. In this way, he divided one interval into four equal quarters to apply the rules of western harmony on them. This alteration was too subjective and abstract to be applicable, and practically it remained as a theory. Aesthetics of intervals in a musical culture, is formed during centuries and millenniums, and changing them if possible, can occur just very slowly and intangible.

Vaziri studied Iranian music with the Farahani brothers. Then he went to Europe and studied the basics of western classical music for five years. The most important achievements of him in music after coming back to Iran are briefly:

- Altering Fundamentally the music education in Iran by establishing the first music school
- Compiling written method for teaching Iranian instruments
- Applying the European noting for teaching Iranian music
- Inventing new signs for the western notation system like *Sori* (▪) and *Koron (𝄐)* based on features of Iranian music

2.6.2 Tetrachord, as the main modal indicator

This is the theory in which *Dang* (tetrachord) is defined as a modal unit in Persian music. In this approach, modal structures are made by combining different *Dang* -s. This combination could be connected or overlapping (Alizadeh 2000, Talaie, Kiani 1989).

According to this viewpoint, *Dowr* (octave) is made by combining two *Dang*-s and adding one major second *Tanini* interval at the end of joint *Dang*-s. This perspective matches on one hand and to some extent, with the theories discussed in the old texts, and on the other hand is significantly in accordance with the practical reality of current Iranian music theory. This perspective is discussed more in chapter 2.7 in more detail.

2.6.3 Trichord, tetrachord and pentachord as the modal core

In this theory in addition to the tetrachord, elements smaller and bigger than tetrachord (trichord and pentachord) are considered as the Structural components of scales. Nariman Hodjati (1999), and Houman Asadi (2008), were the first introducers of this idea.

Houman Asadi is one of the first music theorists who has tried to combine the Iranian old theory of music with the modern musicological concepts, to explain the executive reality of the modal structures in Iranian *Dastgah* music. He introduces the modal structure of Iranian *Dastgah* music in the modal cells, smaller and bigger than the tetrachords like trichord and pentachords (Asadi, Doctoral dissertation, 2008).

Musical ideas in Iranian music find their identities in structures with three, four or five notes trichord, tetrachords or pentachords), not in a seven or twelve notes structure. All these structures regardless of the numbers of their elements (three, four or five), have three main recognizable properties.

1. Specified structure between the intervals of the notes
2. One note is defined as the centre of gravity of the structure (*Shahed* and *Ist*)
3. Potential possibility of temporary change of *Shahed* from one note to another in the same structure (change the *Shahed*).

So, an Iranian musical mode is the combination of these three main properties, which comprise the structure of the intervals, central note and melodical behaviour patterns. Iranian music is modal music, and the foundation of this musical culture is based on different *Maqams*. Although Talai(1993), believes that the best translation for mode is Mayeh but Fayyaz (2012), uses Maqam as the best equivalent for mode. Iranian *Dang*-s (tetrachords and pentachords) have enormous potential to combine, adhere and intermelt. Accordingly, one can say that Iranian music has a mosaic kind texture. Small tiles make greater patterns in connection to each other and structures with three, four or five sounds (trichords, tetrachord and pentachord) constantly combine in different forms longitudinally and create new scale.

For instance, this pentachord, illustrated in Figure 7, could be introduced as the basic core for *Avaz* Afshari.

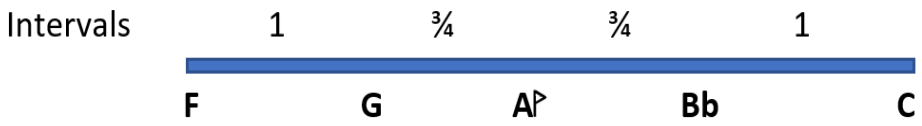


FIGURE 7. Basic core for *Avaz* Afshari.

But when it is divided into two trichords it will introduce the basic core for *Segah*, as illustrated in Figure 8.

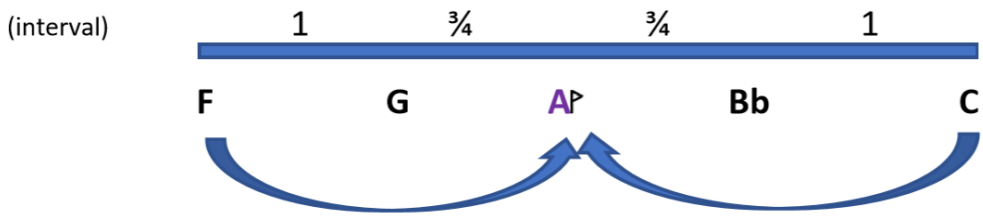


FIGURE 8. Basic pentachord for *Segah.*

Here there are two trichords with same intervals, one upward and other downward, both ends on Aq as the centre point.

Although, the valuable attempts of the mentioned musicians and theorists has been such a great facilitator in explaining the modal structure of Iranian music, it seems that, considering the structural complexity of this music, we are still far from finding an accurate and comprehensive theory that explains it.

In this study, the intervals and their size is measured and analysed, so we do our research based on the second point of view and do our study on 4 different *Dang*-s in Persian music which are *Shur*, *Mahoor*, *Dashti* and *Chahargah*.

2.7 Tetrachords

Since a few thousand years ago, at least from the time of Pythagoras, Knowledge of music has acknowledged the value and importance of the four-note structure which it is called by the Greek name, tetrachord. The medieval music theorists like Al-Farabi, Safiaddin Ormavi and Maraqi believed that tetrachord is the most significant modal indicator, which is called *Dang* in Persian and Zolarba in Arabic (talaie,1993). Iranian musician, Farabi, named it Zolarba' in his books, that refers to the four-elements structure. He discusses its importance in detail about 11 centuries ago. Then eight hundred years ago, Safiaddin Ormavi, the well-known musician of the thirteenth century introduced the consonant tetrachords (Matbou zoul arbas*)* to be seven (Ormavi, 2011). From three hundred years ago onward, when Iranian music was little by little differentiated from its historical cousins, the Turkish and Arabic music, the tetrachord structure

is called *Dang* in the Iranian musicology discourse. In the contemporary era, *Dang*-s and their undeniable role in shaping the Iranian music has been increasingly noticed. Nowadays, the concept of *Dang* or tetrachord is mostly of a theoretic place in western music and not much more value.

Talai (1993) believes that all Iranian modes could be analysed and performed based on four different forms of *Dang*-s which are illustrated in the Figure9:

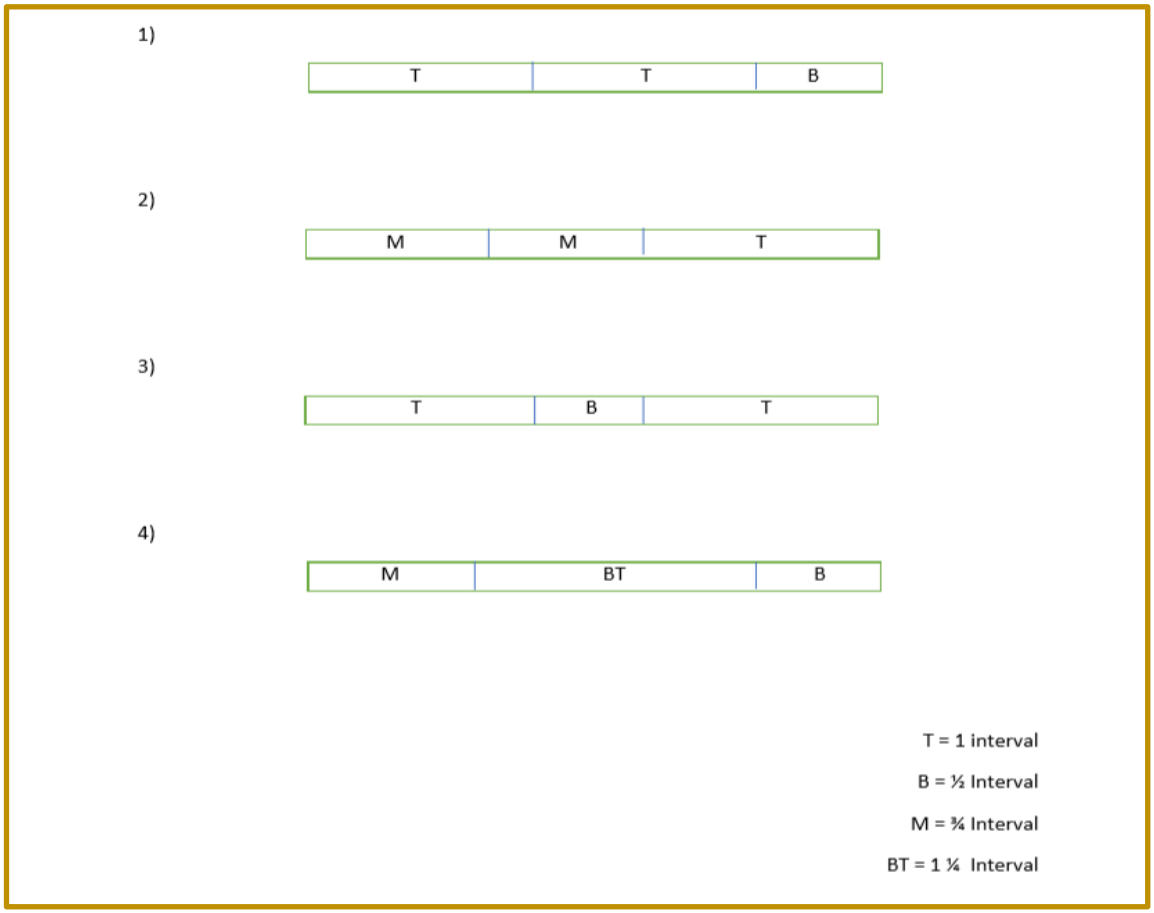


FIGURE 9. Four different forms of Dangs by Talai, four notes in a dang and three intervals between them.

Other musicians and theorists like Alizadeh, Asadi, Oftadeh, Bayani, Kamal poortorab & Fatemi (2005) added 2 more tetrachords to Talai's list which are illustrated in Figure 10.

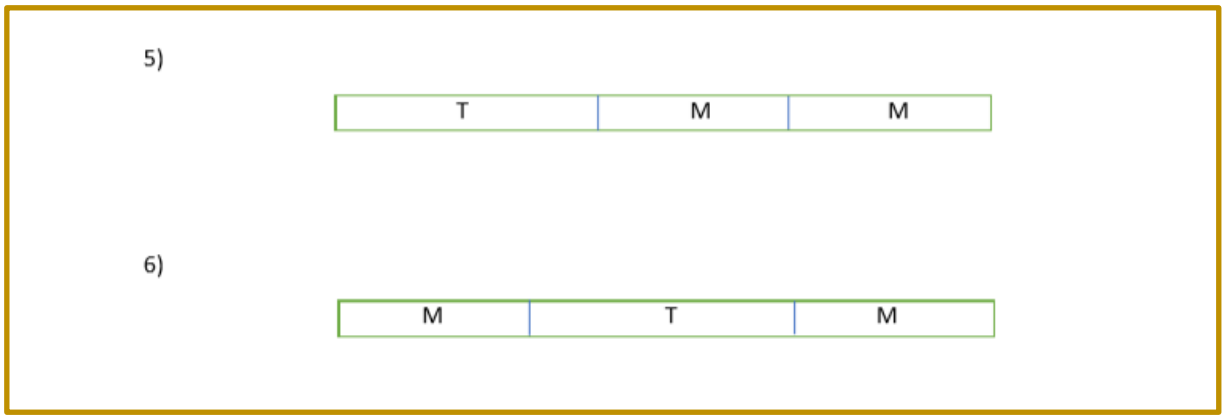


FIGURE 10. Two additional tetrachords by Alizade & et al.

Mehrani (2002), added the number seven to this list. shown in Figure 11.

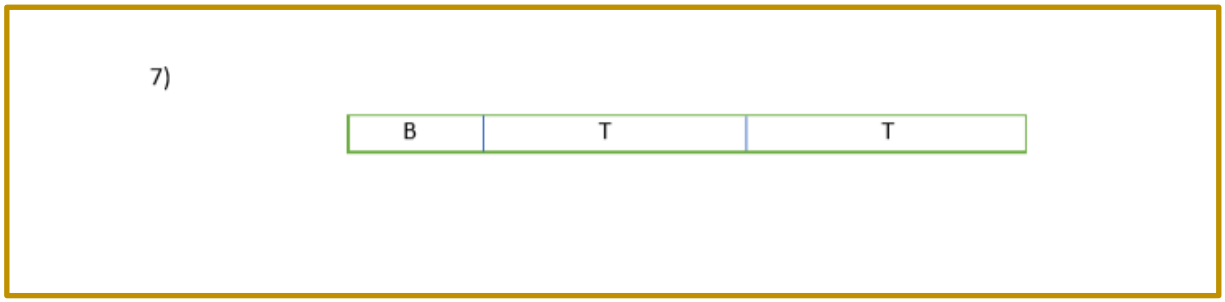


FIGURE 11. The seventh tetrachord by Mehrani.

Mehrani (2002), mentioned that the tonic or the stop point of a Dang could be the first or the last note, because the centre of gravity in a tetrachord could be one of them. Based on this idea he defined 2 different tetrachords with the same interval structure. So, he certainly believes that there are 14 different *Dang*-s in Persian music. He chose a name for each of them. They are *Rast, Däramäd Mahoor, Däramad shur, Shähnaz, Däramad Chahargah, Chäkaväk, Näva, Pärvaneh, Rohhab, Äraghe Äfshari, Bäyate raje, Ooje raje, Däramäd Segah, Däramad Homayoon*.

It is clear that each pair of these *Dang*-s have the same intervals, and the difference is just on their stop point. All 14 *Dang*-s of Mehrani are shown in the Figures number 12 to 18.

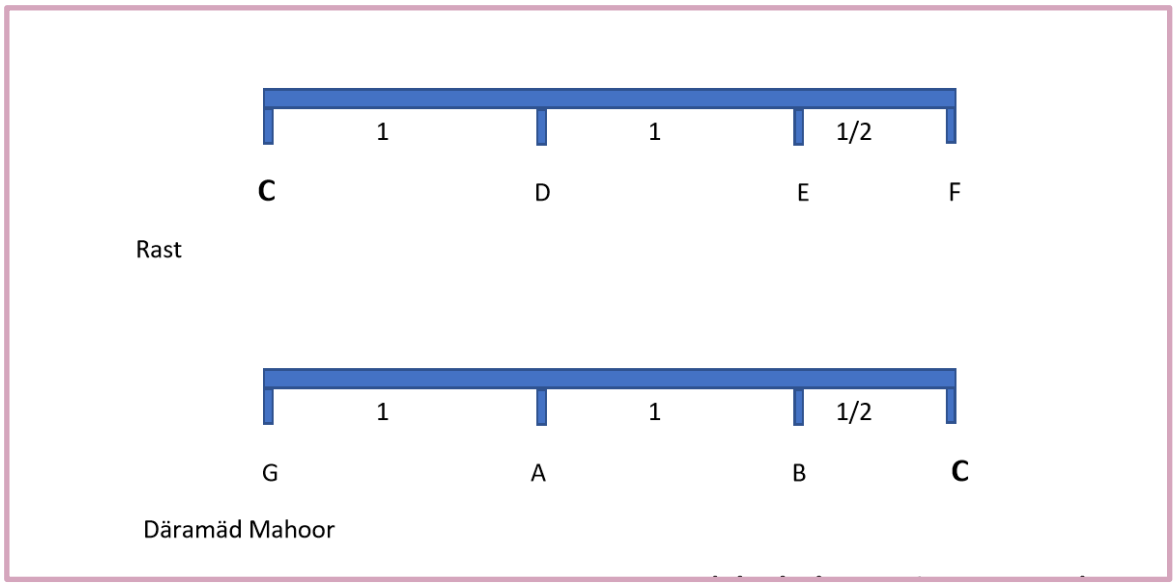


FIGURE 12.

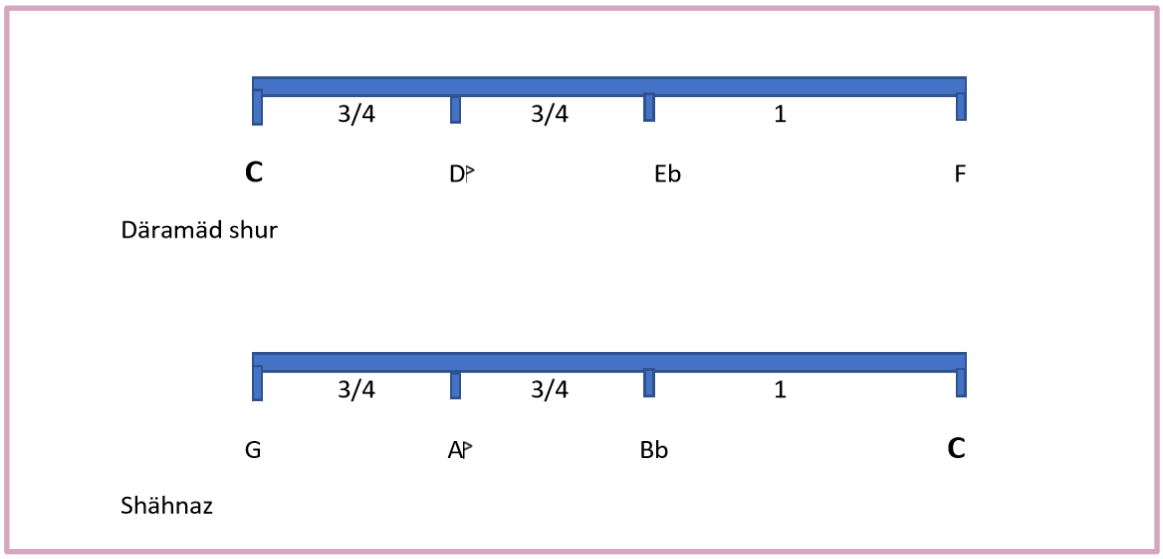


FIGURE 13.

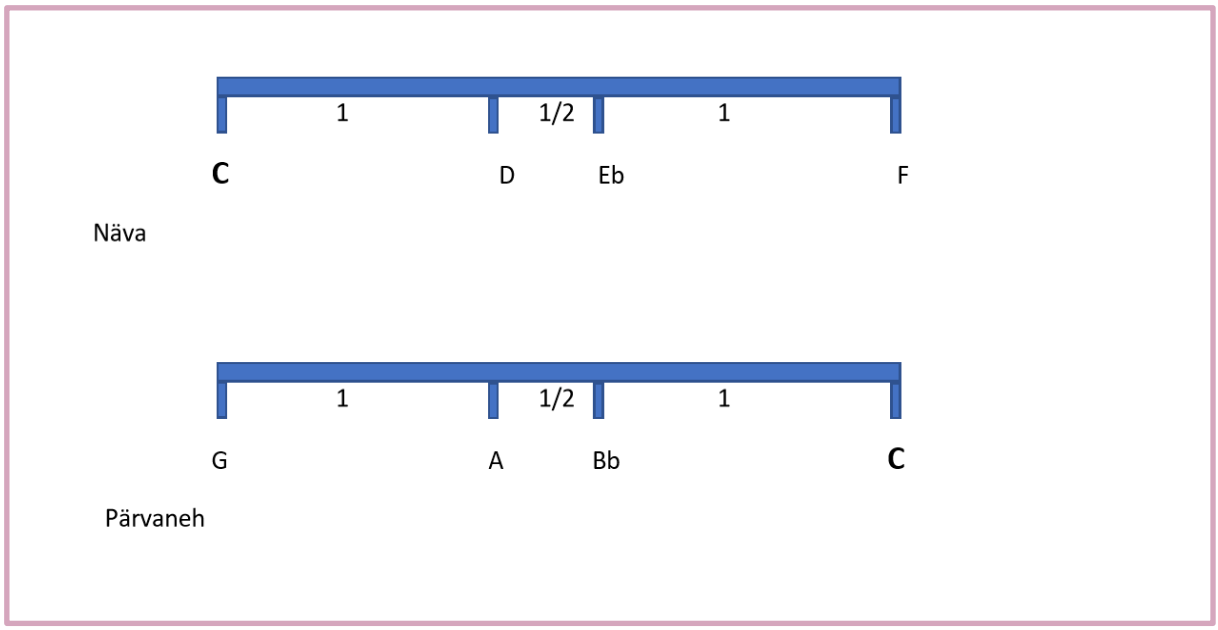


FIGURE 14.

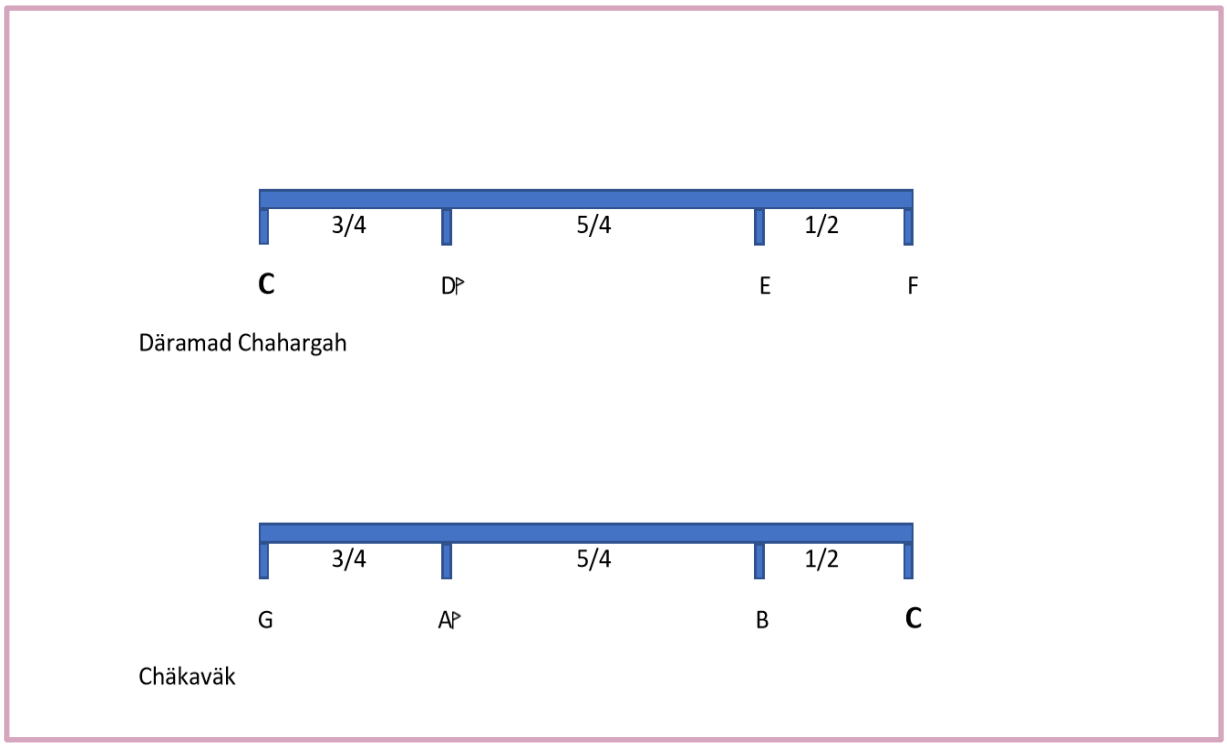


FIGURE 15.

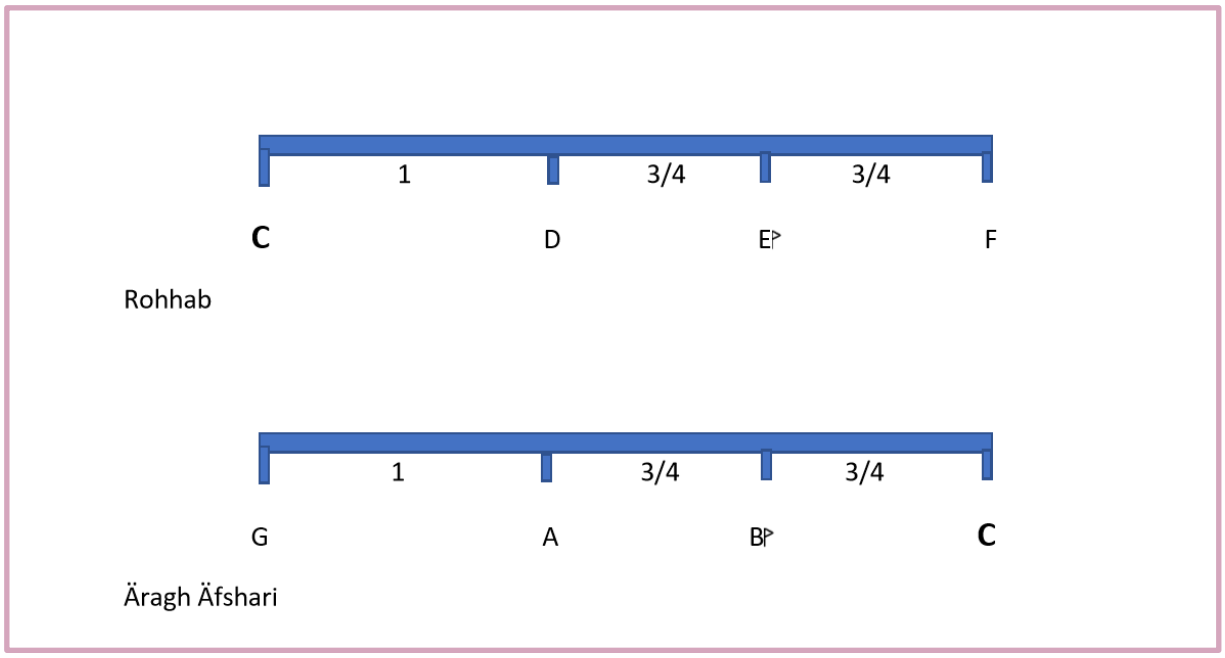


FIGURE 16.

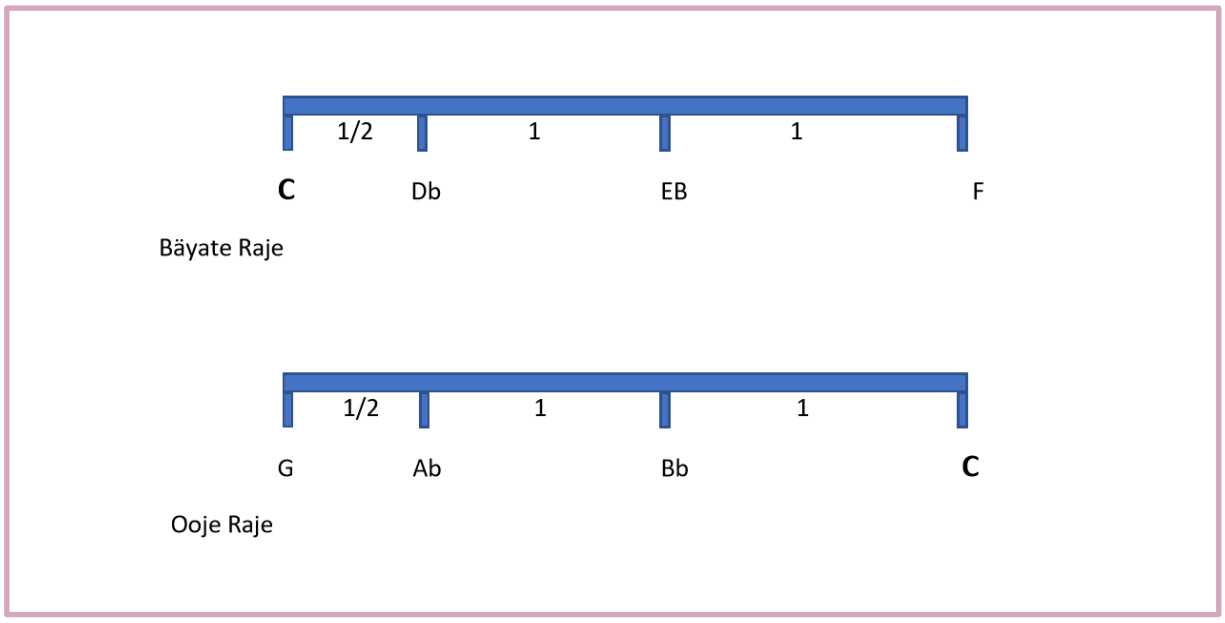


FIGURE 17.

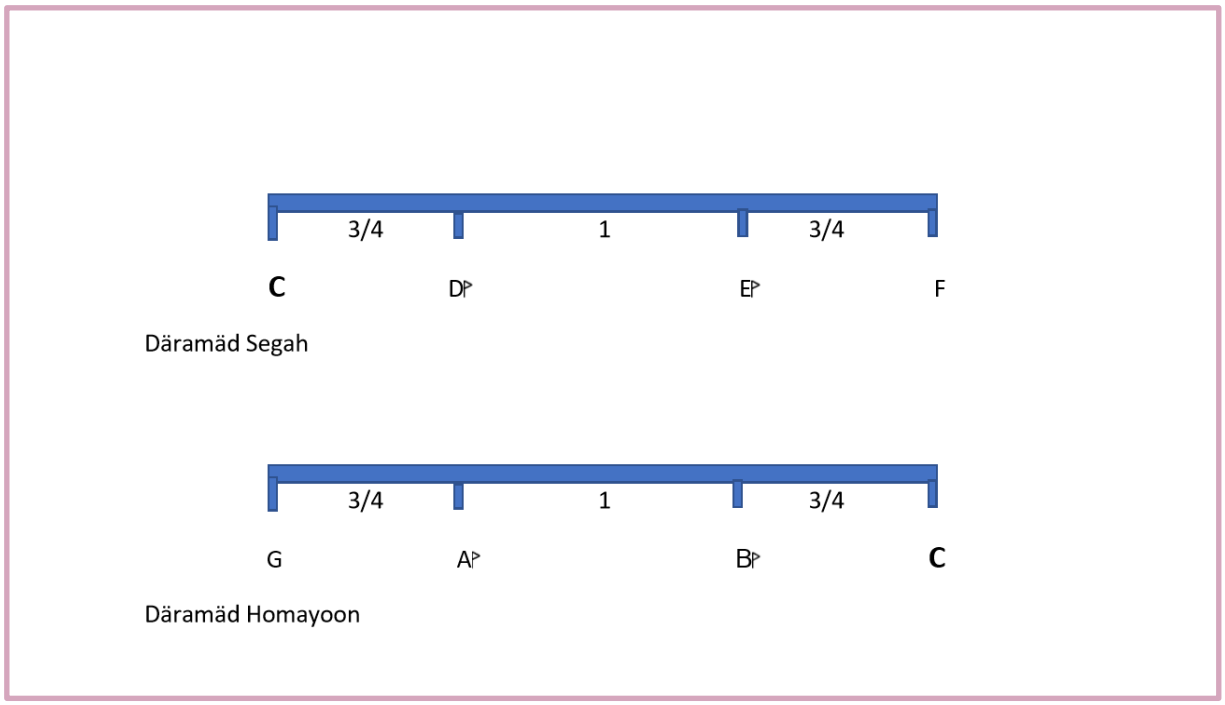


FIGURE 18.

Normally, the melodical amplitude of a melody is more than a tetrachord, so in a development of a melody we need to pass one tetrachord and enter a second one and third one, which results in different combinations of tetrachords.

Since this study is just about the intervals and their size in Persian music, and regardless of theoretical discussion about the fundamental concepts in Persian music, such as octave structure versus tetrachord base structure, and the quantity of the tetrachords in Persian music, tetrachord oriented approach and Talai (1993) idea about four identical tetrachord in Persian music is considered as the base for this study. As Talai (1993) mentioned All modes in Persian music are made from four different *Dang*-s (tetrachords). They are characterized in Figure 19.

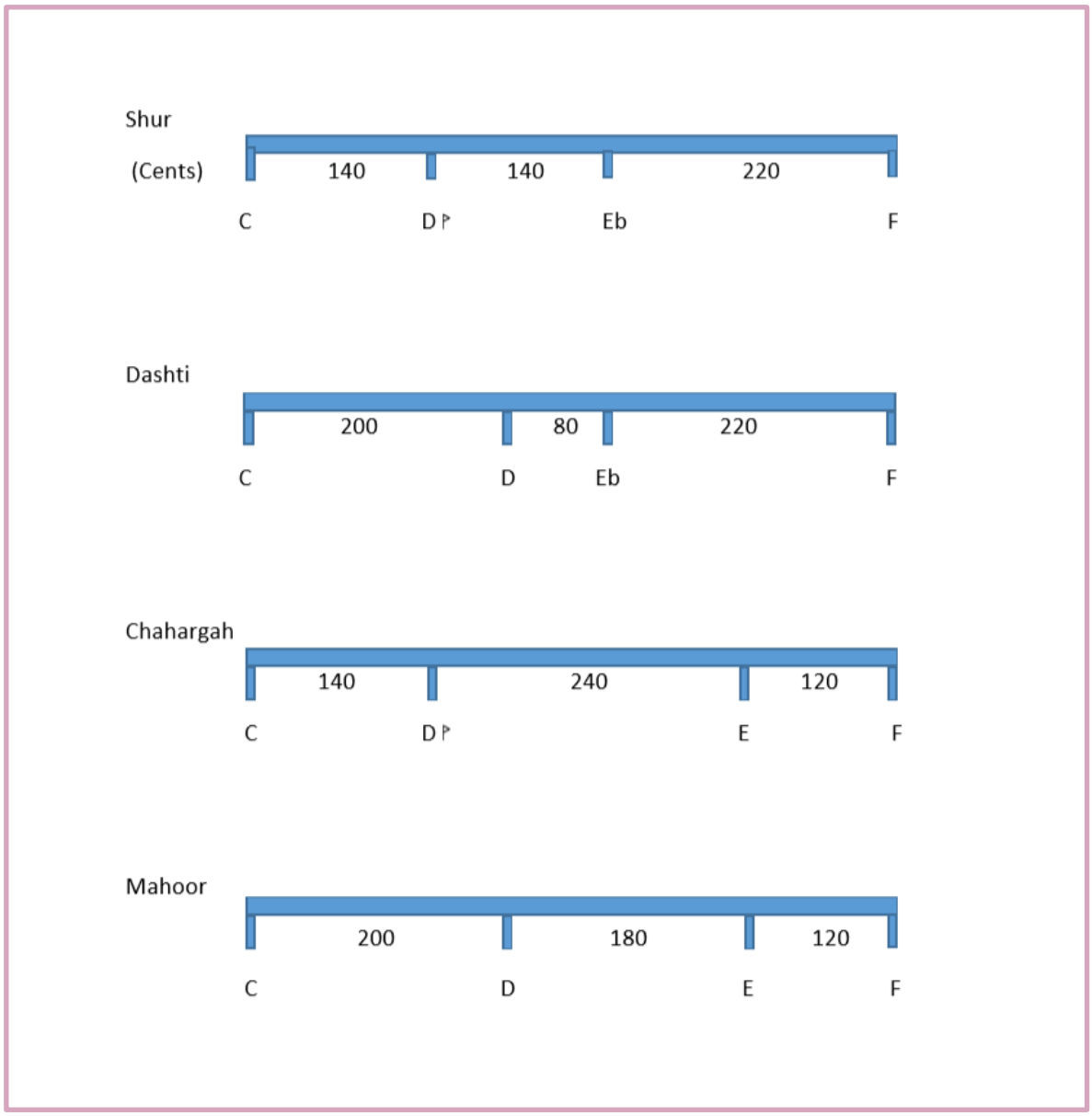


FIGURE 19. Four basic Dang-s in Persian music.

3 METHODOLOGY

Despite the tremendous amount of studies done on the field of Music Information Retrieval (MIR), that has turned it into a vast area of different subjects, the problem of gap between western music and other traditions of music has remained unsolved. Particularly, the Middle Eastern music culture is one that its relation with western music is not analysed properly. Moreover, the amount of research done on Persian music, compared to other members of this family, such as Turkish and Arabic, with all similarities and overlap among them, is still less.

3.1 Theories

Two main theories were assumed as the base of the analysis.
First theory which is displayed in Table 5 proposed by Ali-Naqi Vaziri (1913), is based on the 24 EDO scale, in which each whole interval is 200 cents and half interval 100 cents and three-quarter interval 150 cents. Table 6 shows the second theory of intervals which was introduced by Talai (1995).

TABLE 5. Intervals of the main four *Dang-s* proposed by Vaziri (1913).

Dang	1st	2nd	3rd	Dang length
Shur	150	150	200	500
Chahargah	150	250	100	500
Dashti	200	100	200	500
Mahoor	200	200	100	500

TABLE 6. Intervals of the main four *Dang-s* proposed by Talai (1995).

Dang	1st	2nd	3rd	Dang length
Shur	140	140	220	500
Chahargah	140	240	120	500
Dashti	200	80	220	500
Mahoor	200	180	120	500

3.2 Stimuli

The stimuli were extracted from musical recordings played by six different Iranian Ney players. Each player played 4 pieces in all 4 Iranian main tetrachords (Talai, 1995), which are *Shur, Chahargah, Dashti* and *Mahoor*. The structure and intervals of the tetrachords are shown in Figure 20. Length of each Piece is between 5-15 seconds in which players play a melody that includes all the tones and intervals of the specific tetrachord (four tones and three intervals). Players were chosen from 2 different generations. Hassan Kasai (Born:1928), Abdol-Naqi Afsharnia (1951), and Kiani Nejad (1952), were categorized as the old generation and Hushmand Ebadi (1970), Siamak Jahangiri (1972), and Shahoo Andalibi (1974), were classified as new ones. Players were tagged below in Table 7.

TABLE 7. List of the players, and their tag

Player	Birth	Tag
Hassan Kasai	1928	Old1
Abdol-Naqi Afsharnia	1951	Old2
Mohammad ali Kiani Nejad	1952	Old3
Hushmand Ebadi	1970	New1
Siamak Jahangiri	1972	New2
Shahoo Andalibi	1974	New3

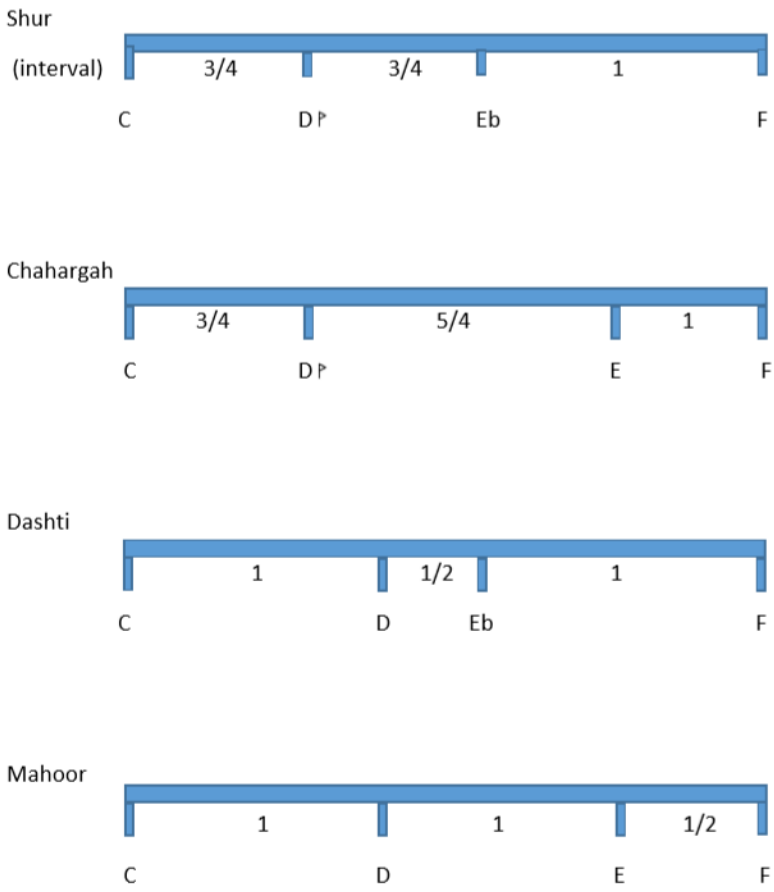


FIGURE 20. Four main tetrachords (Dang) in Persian music.

3.2.1 Persian ney

Ney, the Iranian wind instrument is made from cane, and some holes are added on it to be touched by fingers. It is likely that a small cylinder of brass or plastic is also added at the end of it to support the fragile cane that has no influence on the sound making. An image of Persian ney is shown in Figure 21.

FIGURE 21. Persian ney

The method of playing Persian ney, that causes it to have a special sound, is different with the ones of other similar wind instruments. Playing starts with putting the upper end of the ney, between two upper teeth, supported by lower teeth and lip and the top lip keeps the top part of the ney surrounded. Tongue has also a role in sending a stream of air into the ney. The pitch and its quality are manipulated by movements of lips and tongue. The pitch can be altered in as big as the up and down directions of a whole tone. Divers kinds of timbre can be produced and the sound varies from the highest to the very low. This traditional method of playing is so difficult to learn. Although, while the player is skillful enough, will have as much control on the sound, as a singer has on his/her own voice. Sound of the ney might vary highly depending on the skill and mastery of the player who needs to control the high and low volume of the air stream, having potential for vast spectrum from pure tones to a highly breath like sounds.

Persian ney is not the only one among different kinds of neys played in the middle east. There are also Arabic and Turkish ney. Lips are the main limb for playing them and none of them produce as vast spectrum of sounds as Persian ney does. There are three bottom holes in Arabic and Turkish ney, instead of two in Persian. Position of the thumb hole is also different in these kinds, which is higher compared to Persian ney that the note made by it when not touched is a semitone higher. Number of segments in Turkish and Arabic neys is nine, while seven in Persian. Interdental is not the only way of playing Persian ney, lips can also play the main role, but these two cannot happen in the same time, because the lips are used and a semitone sound is produced. The oldest ancestors of neys have been discovered in Egyptian tombs 5000 years ago.

3.3 Pitch extraction with MIRtoolbox

For this study MIRtoolbox is used which is designed to be used inside MATLAB to extract and analyse audio features such as pitch, timbre, tonality and others. There are several useful functions in this toolbox which make analysis much easier for the researcher.
In this study mirpitch is used for extracting the pitches. Figure 22 shows the procedure of mirpitch.

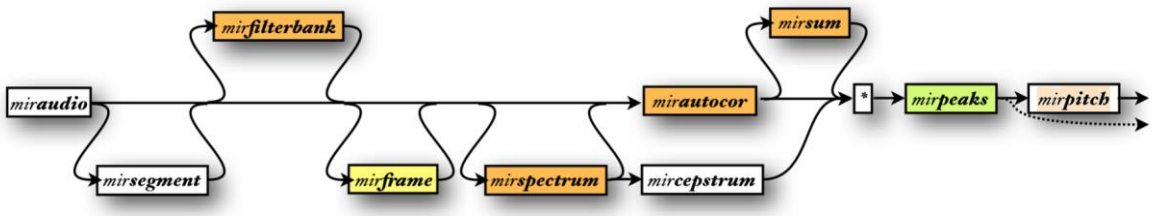


FIGURE 22. Procedure of mirpitch.

First miraudio is used to get the input data. Then the audio signal is decomposed into a series of audio signals of different frequency registers, from low frequency channels to high frequency channels. This is done by mirfilterbank. Next mirautocor is used to evaluate periodicities in the audio signals consists in looking at local correlation between samples. And mirsum command is used to sum back the channels, then mirpeaks for peak peaking and at the end mirpith is used to extract the pitches. (Lartillot, 2012)

For tuning the peaks, the Mono option is used, this option selects only the best pitch. For the frame decomposition 'Frame' is used. With a default frame length of 46.4 ms and a hop factor of 10 ms (Tolonen & Karjalainen, 2000). To extract the intervals in cent, as a post processing option 'Segment' option is used. This option segments the obtained monodic pitch curve in cents as a succession of notes with stable frequencies (Figure 23). Then pitches were extracted from the figures and the mean value of pitches by threshold of 50 cents were calculated. detailed data is demonstrated as an appendix at the end of this paper. It includes 4 main tetrachords and three intervals for each tetrachord.

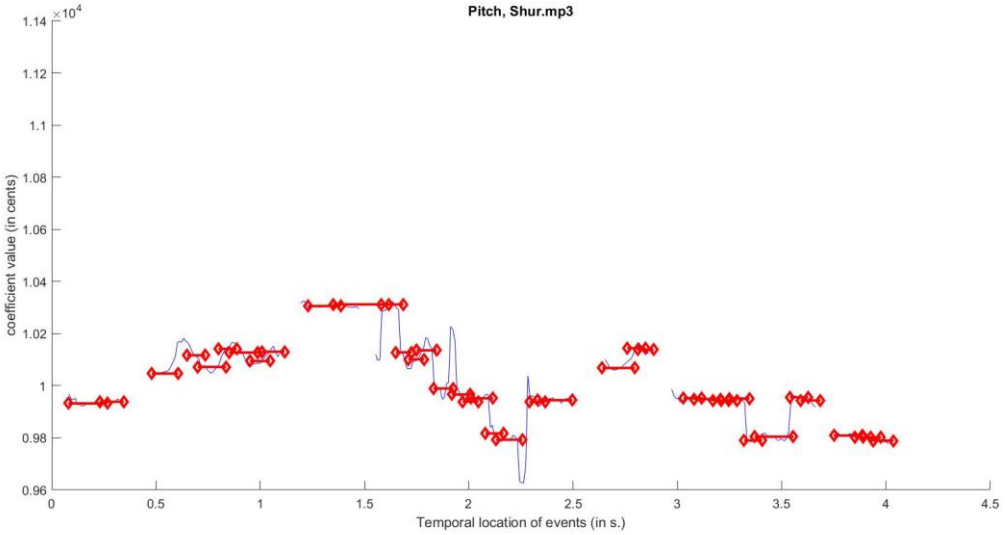


FIGURE 23. Pitch results from mirpitch

3.4 Statistical analysis

Each of six players played a piece in each of the four tetrachords. So altogether 24 stimuli. Each stimulus includes 4 tones and 3 intervals. Players were categorized in 2 groups, old and new generation, and each group includes 3 players. The frequencies of the tones were extracted and the intervals were calculated in cents. Mean and standard deviation of all intervals were calculated. Correlation and partial correlation were run between the intervals played by each group and theories also between players and theories. Also, Two-sample t-test was carried out to compare distributions of the groups for each interval type.

4 RESULTS

This section will report the results. First it will demonstrate the conformity of the intervals played by each six players and the two main theories in this subject. Secondly, The mean of intervals which are played by both groups (as mentioned previously, players are categorized in two groups, old and new) were calculated and the conformity of the mean values of each group and the theories were checked. Then the partial correlation between each player and a theory, also between each group and one theory were evaluated, while other theory was controlled. Then a two-sample t-test was conducted to compare distributions of the groups for each interval type and, finally the results were visualized to make the results more understandable for readers.

4.1 Visualized results

Played intervals are visualized in figure 24. All three intervals of four main tetrachords in Persian music, which are *Shur, Chahargah, Dashti* and *Mahoor*, played by six players (three players of old group and three players of new group) are demonstrated in comparison to both theories. Theory 1 is Vaziri's (1913) theory and second theory is theory proposed by Talai (1995).

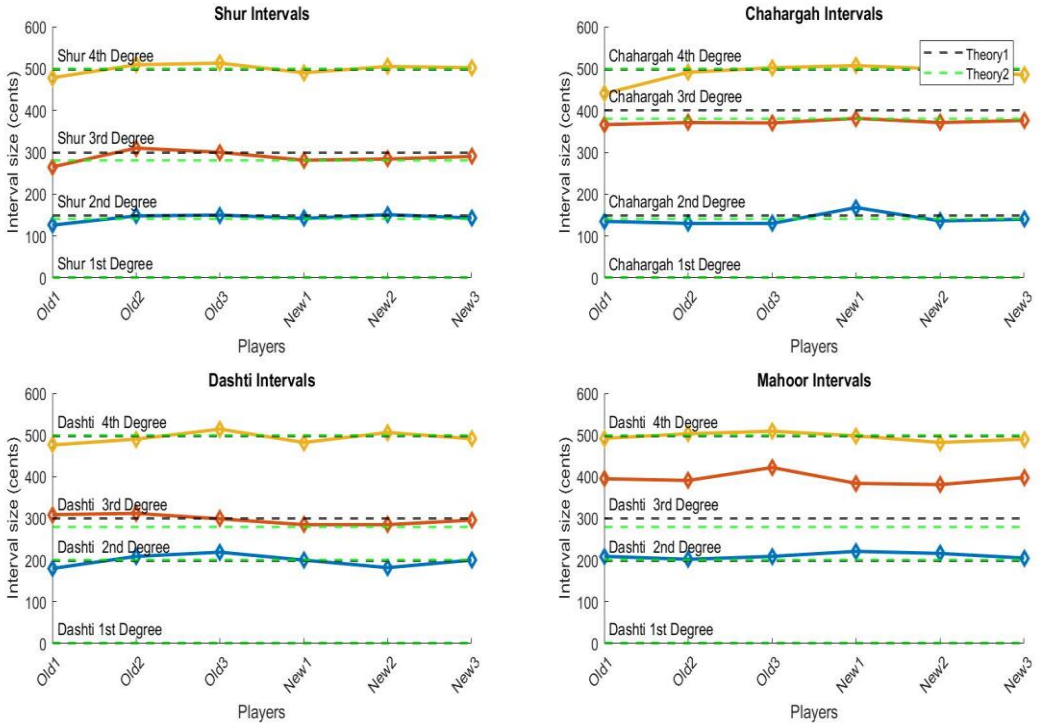


FIGURE 24. Intervals of all four main tetrachords in Persian music played by six players in comparison to both theories

4.2 Mean and standard deviation of players in each group

To summarize interval sizes within groups, mean and standard deviation were calculated. Results are shown in Tables 8 and 9.

TABLE 8. Mean and SD of the intervals played by old players.

Interval	Old1	Old2	Old3	Mean	SD
Shur1	126	148	150	141	13.31
Shur2	139	162	150	150	11.50
Shur3	213	199	213	208	8.08
Chahargah1	135	130	130	132	2.88
Chahargah2	231	241	240	237	5.51
Chahargah3	74	120	132	109	30.61
Dashti1	180	209	219	203	20.25
Dashti2	129	103	80	104	24.51
Dashti3	167	178	215	187	25.14
Mahoor1	209	202	209	207	4.04
Mahoor2	186	189	213	196	14.80
Mahoor3	97	112	87	99	12.58

TABLE 9. Mean and SD of the intervals played by New players.

Interval	New1	New2	New3	Mean	SD
Shur1	142	151	143	145	4.93
Shur2	139	133	147	140	7.02
Shur3	209	221	212	214	6.24
Chahargah1	168	136	133	146	19.40
Chahargah2	213	235	226	225	11.06
Chahargah3	126	128	113	122	8.14
Dashti1	200	182	206	196	12.49
Dashti2	85	103	87	92	9.86
Dashti3	197	221	211	210	12.05
Mahoor1	221	216	205	214	8.18
Mahoor2	163	165	167	165	2.00
Mahoor3	114	101	108	108	6.50

According to table 8, old player played *chahargah*1, *chahargah*2 and *mahoor1* closer to each other. The SD for *chahargah*1 is 2.88, for *chahargah*2 is 5.51, and for *mahoor*1 is 4.04.

Based on the Table 9, the new players play the *Shur* and *Mahoor* tetrachord more precisely. The SD for *shur* first interval is 4.93, for *shur* second interval is 7.02 and for *shur* third interval is 6.24. and for *Mahoor* tetrachord the SD is 8.18, 2.00 and 6.50 for *Mahoor*1, *Mahoor*2 and *Mahoor*3 intervals.

4.3 Interval size correlation between players and the theories, groups (old and new) and theories

The current study evaluates relationships between the pitches and intervals of four main tetrachords (*Shur, Dashti, Chahargah and Mahoor*) and two main theories (Vaziri and Talai) about them in Persian music. Interval size Correlation data revealed that intervals played by players are highly correlated with both theories (Table 10). But it seems that old players are more correlated with first theory while new players' intervals are more correlated with theory number two (Table 11). Benjamini-Hochberg false discovery rate procedure (1995), is used to adjust p-values for multiple comparisons. The desired false discovery rate considered as q= 0.05.

TABLE 10. interval size correlation between players and theories.

	Old1	**Old2**	**Old3**	**New1**	**New2**	**New3**	**Theory1**
Old2	.91***	—					
Old3	.85***	.96***	—				
New1	.84***	.89***	.91***	—			
New2	.87***	.90***	.93***	.94***	—		
New3	.88***	.95***	.96***	.96***	.97***	—	
Theory1	.93***	.97***	.96***	.90***	.92***	.95***	—
Theory2	.86***	.93***	.95***	.95***	.96***	.99***	.95***

Note: ***p <.001

TABLE 11. Correlation relationship between groups and theories.

	Old	**New1**	**Theory1**
New	.95***	—	—
Theory1	.98***	.94***	—
Theory2	.95***	.98***	.95***

Note: ***p <.001

4.4 Partial correlation between players' intervals and theories

Partial correlations were conducted between intervals of each player and one theory, while other theory was controlled (Table 12). When we control the second theory on the relationship between players and the first theory, following partial correlation were observed between Kasai (old1) and first theory (r= .72 and p = .012), and between Afsharnia (old2), and the first theory (r=.72 p= .012). When the first theory was controlled on the relationship between players and the second theory, following partial correlation could be seen between Jahangiri (new2), and second theory (r= .73 and p= .010), and also between Andalibi and the second theory (r= .86 and p<.001). Benjamini-Hochberg false discovery rate procedure (1995), is used to adjust p-values for multiple comparisons. The desired false discovery rate considered as q= 0.05.

TABLE 12. Partial Correlation between players' intervals and theories.

	Kasai (Old1)	**Afashrnia (Old2)**	**Kaininejad (Old3)**	**Ebadi (New1)**	**Jahangiri (New2)**	**Andalibi (New3)**
Theory1	.72*	.72*	.54	.06	.07	.29
Theory2	-.22	.20	.52	.65	.73*	.86***

Note: *p< .05, ***p<.001

4.5 Partial correlation for intervals played by each group with theories

Partial correlations were conducted between each group (old and new) and a theory while controlling the other theory. First theory 2 is controlled on the relationship between old group intervals and theory 1, then theory 1 is controlled on the relationship between old group intervals and theory 2. Results for partial correlations are displayed in Tables 13. A significant partial correlation is observed between the intervals played by old players and the first theory (r = .83 and p<.01**),** And there was a significant partial correlation between new player's intervals and the second theory. (r = .83 and p<.01).

TABLE 13. Partial correlation between groups and theories.

Controlled variable		**Old**	**New**
Theory 2	Theory1	.83 **	.16
	Theory2	—	—
Theory1	Theory1	—	—
	Theory2	.27	.83**

Note: ** p <.01

4.6 T-tests

Two-sample t-tests were conducted to compare distributions of the groups for each interval type. Benjamini-Hochberg false discovery rate procedure (1995), is used to adjust p-values for multiple comparisons. The desired false discovery rate considered as q= 0.05. None of the comparisons reached significance but based on Figure 25 it could be observed that there is a difference in interval size between Old and New group for Mahoor2 interval (the interval between second and third degree of *Mahoor* tetrachord).

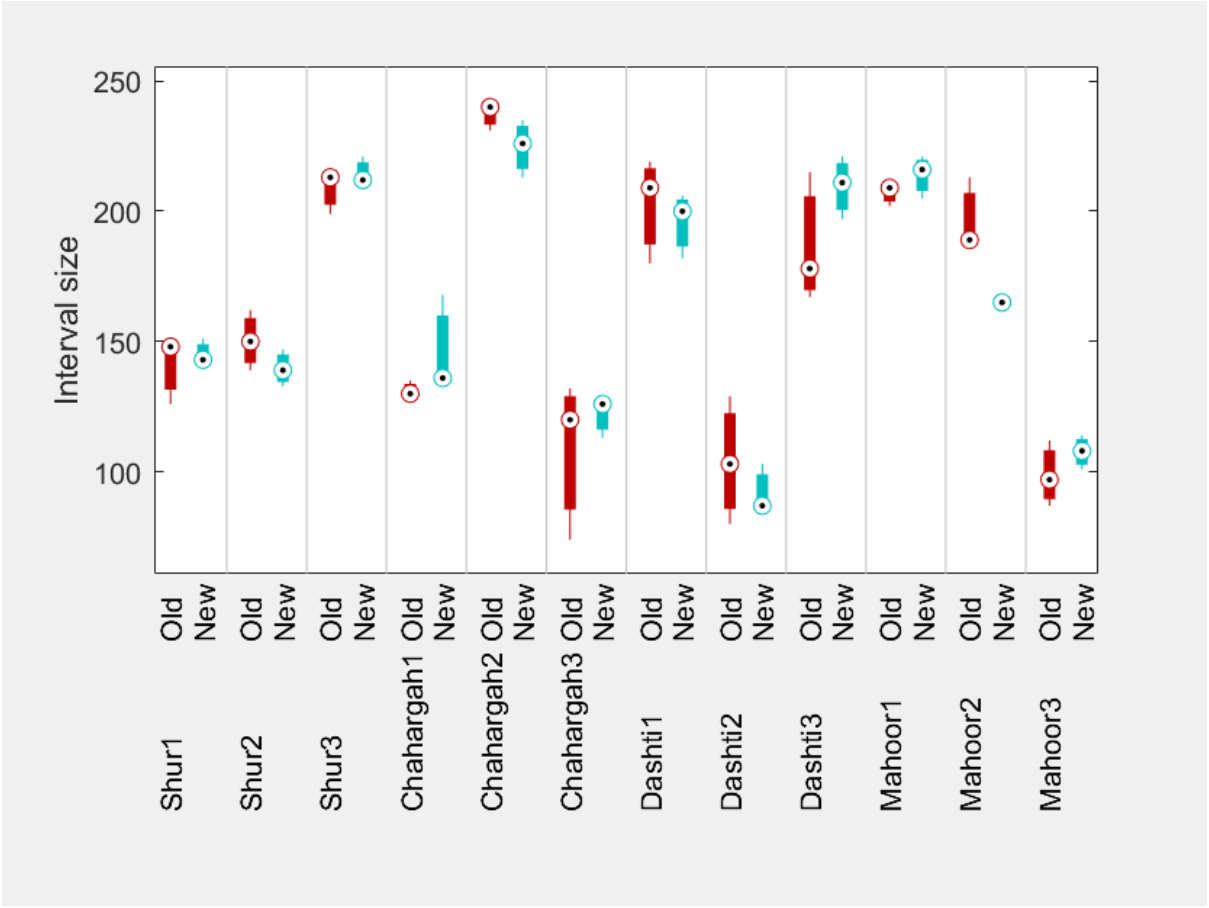


FIGURE 25. boxplot to compare distributions of the groups for each interval type.

5 DISCUSSION

The following section will begin with a discussion of the implications of the results. It will then move into some of the limitations of this study, and finally, some possible future directions to take**.**

The purpose of the current study was to gain new insights into the size of the intervals in Persian Dastgah Music. Six players were categorized into two groups, old generation and new generation (each group 3 players). 24 short pieces by 6 Ney players (each player played all 4 main tetrachords) were used as the stimuli. MIRtoolbox was used to extract the pitch of each degree of the tetrachords, then intervals between the degrees of tetrachords were calculated and compared with 2 main theories, Vaziri (1913), and Talai (1995).

All six players' intervals are correlated with both theories (Table 8), but it seems that the old players intervals are more correlated with theory one, old 1(r= .93 and p<.001), old2(r=.97 and p<.001) and old 3(r = .96 and p<.001), while the new players intervals are more correlated with theory number 2. new1 (r= .95 and p<.001), new2 (r= .96 and p<.001) and new3 (r= .99 and p<.001). By calculation standard deviation of old players interval (Table 8), old players played the first interval of *Chahargah* tetrachord more precisely than other intervals (SD=2.88), while the least precise interval played by old players was *Chahargah*3. (SD = 30.61). For new players (Table 9), the most precise interval was *Mahoor*2 (SD=2.00), and they played chahargah1 (SD=19.40) less precise than all other intervals. Both old and new generations played *Mahoor* tetrachords more precisely than all other tetrachords. The possible reason might be the intervals of this tetrachord, as there is not any microtone between the degrees of *Mahoor*. Correlations between groups and theories are as follows: group one is correlated with both theories. Correlation between the first group and the first theory is (r= .98 and p<.001) and with the second theory (r= .95 and p<.001), while the correlation coefficient between the new generation and the first theory is (r= .94 and p<.001), and with the second theory (r= .98 and p<.001). This is while, the correlation between theory one and theory two is (r= .95 and p<.001). By conducting a two-sample t-test between the groups to compare the distribution for each interval type, there was not any significant difference between the groups.

The issue of intervals and pitches in each musical culture could have a unique structure (which could be completely different than the standards of the classical western music), and sometimes has several different theories about each interval at the same time however, the musician finally decides to increase or decrease an interval size by some cents according to his mood. On the other hand, sometimes non-standard instruments with old structures makes it difficult for musicians to play accurate intervals.

Farabi is the first person in the history of Persian music who put forward the concept of intervals, that was applied in Iranian and Arabic music for centuries. Later in the 15th century, Abdul Qadir Maraqi compiled theory for intervals in Persian music. Next Person in line is Ali Naqi Vaziri, who suggested his theory of intervals based on 24 Edo in early 20^{th} century, which were used for decades but questioned by musicians and theorists of Persian music afterward. Next theories on intervals in Persian music were suggested by Hormoz Farhat and Dariush Talai, but up to this time, there is no specific theory as the main principle on the accurate size of intervals. Accordingly, size of the intervals with same names in performance is not fixed and rather depends on the player mood and the instrument.

It is also remarkable that most of the software, applications, and technologies, which are used in musical research are based on the western standard theories. Thus, evaluating pitch values and interval sizes in ethnic music is one of the most challenging topics in computational ethnomusicology. In addition to the lack of standard theories for these musical cultures, the lack of written references and the lack of translation into the major academic languages of the world are some of the challenges for researching these musical cultures. Since in this research field, researcher has to work with stimuli from different time eras, you have to have access to old recordings, while working on these stimuli will be very difficult and troublesome because basically, few samples are available and secondly the quality of the samples is very low. Finally, as the world's public interest in ethnic and local arts, including world music, has grown in recent decades, one can hope that in the coming years, more research will be done on these arts and cultures.

References

Abdoli, S. (2011). Iranian Traditional Music *Dastgah* Classification. In *ISMIR* (pp. 275-280).

Alizadeh, H. (2000). *Dastur-e tār va setār [tar and setar teaching method]*. Tehran: Mahoor.

Alizadeh. H., Asadi. H., Oftadeh, M., Bayanii, A., Kamal poortorab, M., Fatemi S. (2005). Mabāni-e Nazari va sākhtār-e Musiqi-ye Irani [theoretical foundations and structure of Iranian music]. Mahoor Music Quarterly.

Asadi, H. (2001). Az Maqām tā Dastgāh [From maqam to *Dastgah*]. Mahoor Music Quarterly, 3 (11), 59–75.

Asadi, H. (2003). Bonyadha-ye nazari-ye musiqi-ye klasik-e Iran; dastgāh be onvan-e majmue-ye chand modi [Theoretical Foundation of Persian classical music; *Dastgah* as a multi modal cycle]. Mahoor Music Quarterly, 6(22), 43-56.

Asadi, H. (2006). Mafhum va Sākhtār-e Dastgāh dar Musiqi-ye klāsik-e Iran." Ph.D., Tehran: Tarbiat Modares University.

Asadi, H. (2008). Towards the Formation of the Dastgāh Concept, A Study in the History of Persian Music. In Intercultural Comparison of Maqam and Related Phenomena, edited by Jürgen Elsner and Gisa Jähnichen, 21–28. Berlin: Trafo.

Asadi, H. (2010). Bāznegari-ye Pishineh-ye Tārikhi-ye Mafhum-e Dastgāh [Revisiting the Historical Background of the *Dastgah* Concept in Persian Music]. Mahoor Music Quarterly, 12 (45), 33–62.

Beigzadeh, B., & Belali Koochesfahani, M. (2016). Classification of Iranian traditional musical modes (DASTGÄH) with artificial neural network. *Journal of Theoretical and Applied Vibration and Acoustics*, *2*(2), 107-118.

Darabi, N., Azimi, N., & Nojumi, H. (2006, March). Recognition of *Dastgah* and Maqam for Persian music with detecting skeletal melodic models. In *The second annual IEEE BENELUX/DSP Valley Signal Processing Symposium*.

Darvishi, M. R. (1994). Negāh be qarb : bahsi dar ta'sir-e musiqi-ye Qarb bar musiqi-ye Irān (Westward look: a discussion on the impact of Western music on the (sic) Iranian music: an analytical survey). Tehran: Mahoor.

Benjamini, Y. & Hochberg, Y. (1995) Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society*, Series B (Methodological). 57(1), 289-300.

Fakhreddini, F. (2015). Tajziye va tahlil va sharh-e *Radif* -e musiqi-ye Irani [Analysis and description of Iranian *Radif* Music]. Tehran: Moeen.

Famourzadeh, V. (2005). *La musique persane, formalisation algébrique des structures* (Thesis). Université du Maine.

Farhat, H. (1990). *The Dastgāh Concept in Persian Music*. Cambridge: Cambridge University Press.

Farhat, H. (2004). *The Dastgāh Concept in Persian Music.* Cambrdige: Cambridge University Press. *ISBN 978-0-521-54206-7*.

Fayaz, M. R. (2012). Shenakht-e Dastgāh-ha-ye Musiqi-ye Irani [About the *Dastgah* of Iranian music]. Tehran: Mahoor Institute of Culture and Art. https://www.mahoor.com/fa/cd/490-introduction-to-the-dastgâhs-of-iranian-music

Gelvin, J. L., & Green, N. (Eds.). (2014). *Global Muslims in the age of steam and print*. Univ of California Press.

Hajarian, M. (1999). *Ghazal as a determining factor of the structure of the Iranian Dastgah*. University of Maryland, College Park.

Hajarian, M. (2015). Maqām dar musiqi shenasi-ye Iran [maqam in Iranian musicology]. The center for thegreatIslamic Encyclopaedia. http://anthropology.ir/article/28898

Heydarian, P., (2014). Automatic recognition of Persian musical modes in audio musical signals, London: Metropolitan University.

Hodjati, N. (1997). Bonyanha-ye nazari-ye musiqi-ye Irāni [Theoretical bases of Iranian music]. Tehran: Markaz-e nashr-e samar.

Kalantari, Sara. (2011). Dar jostoju-ye mafhum-e *Radif* [In search for the concept of *Radif*]. Quarterly of Iran House of Music, 1, 19-17.

Kāleqi, R. (2007). Nazari be musiqi [A look to music] (Second ed.). Tehran: Rahroān-e pouyesh.

Khazrai, B.(2009). Taqsim-e vatar va dastebandi-ye sāz az didgah-e Abdolqader-e Maraqi. Tarikhe elm magazine no. 7, 37-54.

Kiani, M. (1989). Haft dastgāh-e musiqi-ye Irani [Seven *Dastgah* of Iranian music]. Tehran: Sarv setah.

Lartillot, O., Toiviainen, P., (2007). A Matlab Toolbox for Musical Feature Extraction from Audio, in Proc. 10th Int. Conf. on Digital Audio Effects.. 237–244.

Lartillot, O. (2012). MIR Toolbox 1.4 User's Manual, Finnish Centre of Excellence in Interdisciplinary Music Research, User Manual.

Lotfi, M. R. (2009). Majmue maqālāt-e musiqi [series of articles on music]. Sheida Annual Book, Tehran: Ava-ye sheida.

Lucas, A. E. (2014). Ancient Music, Modern Myth: Persian Music and the Pursuit of Methodology in Ethnomusicology. *Theory and Method in Historical Ethnomusicology*, 175-195.

Mahler, E. Z. (1973). *Classical Persian Music: An Introduction*. Harvard University Press.

Marāghi, A., (1991). Sharh-e Advār [Interpretation of Advar]. Edited by Taqi Binesh. Tehran: Markaz Nashr Daneshgahi.

Miller, L. C. (1999). *Music and song in Persia: The art of àvàz*. Salt Lake City: University of Utah.

Mohamadi, M. (2017). Modal Modernities: Formations of Persian Classical Music and the Recording of a National Tradition. Utrecht: Utrecht University.

Nettl, B. (1987). *The Radif of Persian music: Studies of structure and cultural context*. Elephant & Cat.

Porter, D. (2015). University of Pennsylvania Library's LJS 235-Kitāb al-Adwār (Video Orientation).

Prout, E. (1903). *Analytical Key to the Exercises in Harmony: Its Theory and Practice*. London: Augener & Company. ISBN 978-0781207836

Toiviainen, P., Lartillot, O. (2007). A Matlab Toolbox for Musical Feature Extraction From Audio, in International Conference on Digital Audio Effects, Bordeaux.

Toiviainen, P., Eerola, T., Lartillot, O. (2008). A Matlab Toolbox for Music Information Retrieval, Springer Data Analysis Machine Learning and Applications,Studies in Classification, Data Analysis, and Knowledge Organization.

Talai, D.(1993). *A New Approach to Theory of Persian art music*. Tehran: Mahoor Institute of Culture and Art.

Talai, D. (1995). *Honare musiqi-ye sonnati-ye Irani: Radif -e Mirzā Abdullāh* [*Traditional Persian Art Music: The Radif of Mirza Abdullāh]*. Tehran: Farhang Moaser.

Talai, D. (1998). *Radif-e Mirzā Abdullāh* [*The Radif of Mirzà Abdullāh]*. Tehran: Mahoor Institute of Culture and Art.

Talai, D. (2015). *Tahlil-e radif* [*Radif Analysis]*. Tehran: Ney Press.

Tolonen, T., & Karjalainen, M. (2000). A computationally efficient multipitch analysis model. *IEEE transactions on speech and audio processing*, *8*(6), 708-716.

Touma, H. H. *(1996). The Music of the Arabs. Portland, Oregon: Amadeus Presslocation. ISBN 0-931340-88-8*.

Van den Doel, K. (1997). The Persian ney. Retrieved from: http://www.persianney.com/

Vaziri, A. N. (1952). *Dastur-e tār*. University of Illinois Library, Photographic Services.

Vaziri, A. (2001). Teori-ye musiqi [Theory of music] (Second ed.). Tehran: Safi Alishah.

Wright, O. (1978). The Modal System of Arab and Persian Music, A.D. 1250-1300. Oxford University Press.

Appendix 1.

Intervals played by each player

Intervals played by Hasan Kassai (1928), (Old 1) are shown in Table 14.

Dang	1st	2nd	3rd	Dang length
Shur	126	139	213	478
Chahargah	135	231	74	440
Dashti	180	129	167	476
Mahoor	209	186	97	492

TABLE 14.

Intervals played by Abdol-Naqi Afsharnia (1951), (Old2) are shown in Table 15.

Dang	1st	2nd	3rd	Dang length
Shur	148	162	199	509
Chahargah	130	241	120	491
Dashti	209	103	178	490
Mahoor	202	189	112	503

TABLE 15.

Intervals played by Kiani Nejad (1952), (Old3) are shown in Table 16**.**

Dang	1st	2nd	3rd	Dang length
Shur	150	150	213	513
Chahargah	130	240	132	502
Dashti1	219	80	215	514
Mahoor	209	213	87	509

TABLE 16.

Intervals played by Hushmand Ebadi (1970), (New1) is shown in Table 17.

Dang	1st	2nd	3rd	Dang length
Shur	142	139	209	490
Chahargah	168	213	126	507
Dashti	200	85	197	482
Mahoor	221	163	114	498

TABLE 17.

Intervals played by Siamak Jahangiri (1972), (New2) are shown in Table 18.

Dang	1st	2nd	3rd	Dang Length
Shur	151	133	221	505
Chahargah	136	235	128	499
Dashti	182	103	221	506
Mahoor	216	165	101	482

TABLE 18.

Intervals played by Shahoo Andalibi (1974), (New3) are shown in table 19.

Dang	1st	2nd	3rd	Dang Length
Shur	143	147	212	502
Chahargah	133	226	113	472
Dashti	206	87	211	504
Mahoor	205	167	108	480

TABLE 19.