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Metrical strength in Persian poetic metres[1]

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In determining the metrical structure of quantitative poetic metres, heavy (i.e. long) syllables are usually associated with metrically strong positions. In this study, examining the case of Persian metres, I argue that the metres must be treated as temporal patterns in music, where research on rhythm perception has shown that the metrical strength of an event is not directly determined by the inter-onset interval following it but sensitive to the overall arrangement of the attack points. To identify metrically strong positions, I introduce a different method based on the performance practices of participants in the poetic tradition. The strength hierarchy is then used to offer constituency trees for the metrical forms and classify them. The structures identified for metrical forms are different from those suggested in previous accounts of Persian metres, in that they allow incomplete constituents at the left edges of metres. Building upon this general framework, a set of constraints chiefly based on well-known universal rhythmic tendencies is introduced and the Persian metre inventory is accounted for as emerging from the interaction of these constraints.

KEYWORDS: metre, metrical accent, Persian metre, rhythm

1. INTRODUCTION

What we refer to as ‘metre’ in music is typically characterised as a hierarchical structure of accents (Lerdahl & Jackendoff 1983, Povel & Essens 1985, Parncutt 1994, Grube & Griffiths 2009). A similar hierarchy of metrical strength is commonly attributed to poetic metre, and it is often assumed that the two structures are closely related. In order to pass as metrical, a line of poetry must be able to be aligned – under certain correspondence criteria – to a hierarchical structure based on metrical strength, which we call a metrical pattern. The correspondence criteria in English metrical poetry, for instance, tend to align weak metrical positions with unstressed syllables (or those not counting as ‘stress maxima’, see Halle & Keyser 1966), while strong positions may be aligned with any syllable.

A common theme in the study of poetic metres has been to treat the contrast between light (monomoraic) and heavy (bimoraic) syllables in quantitative metre in

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the same manner as the contrast between stressed and unstressed syllables in stress-based metrical systems. Under this view, heavy syllables tend to occupy strong positions in the metrical template. This correspondence is sometimes explicitly mentioned in the literature (Fabb & Halle 2008: 153, Hayes & Schuh 2019, Kiparsky 2020) and sometimes assumed via the adaptation of the commonly used scheme described by Kiparsky (2020): a strong position is filled with a bimoraic syllable or at least a bimoraic foot, while a weak position cannot be filled with a bimoraic syllable and sometimes not even with a bimoraic foot. In short, this restricts heavy syllables to strong positions and single light syllables to weak positions.

In spite of their dramatic differences in how they analyse metrical forms, most scholars have followed a similar path to the one described above in their accounts of the relationship between syllable weight and metre in quantitative metrical traditions (see Halle 1970, Golston & Riad 2000, and Prince 1989 on Greek; Schuh 1989 on Hausa; Deo & Kiparsky 2011 on Persian; Fabb and Halle 2008 on Greek and Arabic; and Riad 2017 on Berber). In all of these works, heavy syllables are taken to be strictly or loosely associated with metrically strong positions or serve as heads of metrical constituents. The most notable exception to this general trend is Halle (1970) and Prince's (1989) account of Arabic metrics, in which the units taken to correspond to strong and weak metrical positions are constituents larger than the syllable, known as 'pegs' and 'cords', originally introduced by early Arabic grammarians. However, even under this account, a syllable's weight ultimately determines the metrical positions it may assume.

I argue that treating syllable weight in quantitative systems as parallel to stress in stress-based systems is misleading. To find metrically strong positions in Persian, I examine the rhythmic intuitions of participants in the Persian metrical tradition, showing that the relationship between syllable weight and metrical accent in this tradition is as complicated as that between the lengths of inter-onset intervals (distances between attack points) and metrical accents in music.

Upon hearing music, our mind divides the piece into time intervals and assigns different degrees of prominence to certain points in time. The clearest manifestation of this perceived structure, which we call 'metre', is how we tap to the rhythm of what we hear. The tapping points have a higher degree of 'metrical accent' (as defined by Lerdahl & Jackend 1983) in comparison to other points in the musical piece. It is important to note that the hierarchy of accents that defines metre is a mental construct. These accents may have no physical cues in the musical piece, yet are fundamental to musical listening (Longuet-Higgins & Lee 1984, Grube & Griffiths 2009). Certainly, intensity and pitch differences in the beat pattern can influence the listener's unconscious choice in what metre (i.e. mental accent structure) to assign to it. However, metrical accents are easily perceived even in the absence of pitch differences.

A sequence of musical events of the same pitch and intensity – often called a 'temporal pattern' – can induce different metrical accents in the listener's mind depending on how the events are spaced in time. The effect is in fact so strong that listeners sometimes find it difficult to believe that the musical events they perceive as accented and unaccented are physically identical (Povel & Essens 1985).

What is essential for our purposes is that in perceiving a temporal pattern, the length of the pause following a musical event is not a direct predictor of the degree of accent assigned to the event. As we shall see in Section 4, the literature on the psychology of rhythm has shown that a rather complex combination of factors determines which musical events receive metrical accents. In fact, events preceding longer silence intervals (corresponding to heavy syllables in a syllable sequence) are in certain contexts among the positions with the highest propensity to receive the weakest accent degrees possible. Moreover, in some cases, a temporal pattern may have multiple acceptable metrical analyses with entirely different musical events being aligned with metrically strong positions in each of the analyses.

This paper proposes that poetic metres in Persian (and presumably other quantitative metrical traditions) correspond to temporal beat patterns, with syllable onsets (or beginnings of nucliei) acting like musical events and syllable weight serving as indicator of the lengths of the inter-onset intervals (the silence intervals between musical events). In this system, unlike stress-based systems, the degree of metrical strength assigned to a syllable is not determined primarily by the presence or absence of some preexisting form of linguistic prominence in the syllable. Instead, the form of the syllables determines their degrees of metrical strength in a nonlocal and far more indirect fashion.

Since metrical accents are mental constructs with no physical cues, we must turn to the listener rather than the incoming beat pattern to identify the positions of the accents. Following a common approach in studies of musical metre, I examine how listeners tap to the rhythm to find the accent patterns they assign to verses. Crucially, it shall be argued that these tapping patterns reflect the actual metrical structure rather than an independent text-setting tradition.

Viewing Persian poetic metres as temporal patterns of the sort seen in music is by no means new. Persian and Arab metricists have appreciated this correspondence for a long time (Kiani et al. 2015). Naṣīr al-Dīn al-Ṭūsi (13th century CE), in his treatise on Persian metres, states the following (Eqbali 1991, p. 159, translated by author):

> *Metre (vazn) is a structure based on the arrangement of the order of motions and pauses (ḥarakāt va sakanāt) … if the subject of these motions and pauses are letters of the alphabet, it is called poetry and otherwise it is called rhythm (īqā‘).*

Somewhat more explicitly, he explains in another chapter of his work (Eqbali 1991, p. 169) that:

> *In the science of rhythm in the art of music, it has been established that metres are formed by consecutive events (faqarāt-i mutatābi‘) and harmonious pauses (sukūnāt-i mutanāsib) that fall between these events … And in poetic metre, prevocalic (mutaḥarrik) letters of all kinds serve as events and non-prevocalic (sākin) letters serve as pauses.*

It must be noted that only consonants and long vowels are represented by letters in the Perso–Arabic script. Moreover, Persian and Arabic disallow onset clusters. Hence, al-Ṭūsi is in effect mapping syllable onsets to musical events on the one hand and long vowels and coda consonants to event-less pulses on the other hand. This yields exactly the mora-based correspondence between temporal patterns and linguistic content that shall be explained in Section 3.1.

Among modern linguists, Hayes (1979) partially establishes this connection between linguistic content and temporal patterns by treating heavy syllables as full notes and light syllables as half notes. However, he does not take metrical accents into account and does not base his analysis of metrical structure on the participants' tapping patterns. Schuh's (1988) account of Hausa metres builds on the same idea as Hayes's idea. He divides metres into musical measures, treats heavy and light, syllables corresponding to 2 time units and 1 time unit, respectively, and identifies measures with 5, 6 or 8 time units in the metres. The account Hayes & Schuh (2019) present for the *Rajaz* metre family in Hausa adopts a similar approach. However, in identifying metrically prominent positions, it follows the common trend of simply taking positions that are most likely to be filled with heavy syllables as prominent.

Recently, a new trend among linguists who are themselves participants in the Persian metrical tradition, has focused on the correspondence between musical metre and time signatures on the one hand and Persian poetic metres on the other hand. In his pioneering work, Jali (1993) treats Persian metres as temporal patterns and divides Persian metres into four classes based on their rhythmic properties. He also notes how verse-final pauses during recitation correspond to musical rests. Dehlavi (2000) and Azarsina (2017) go one step further, describing how participants consistently divide Persian poetic metres into measures in fixed patterns with many metres starting with anacruses. It must be noted, however, that none of these works attempt to analyse the hierarchical structure of the metres or give an account of what determines metrical well-formedness in Persian. Rastipoor & Banaei (2019) call to attention the relevance of measures in determining pause lengths (with no mention of accents) and make the important observation that on some occasions, a single syllable sequence can have more than one well-formed metrical interpretation. Finally, Mirzaee et al. (2019) perform an experiment showing that participants are consistent in assigning seemingly nonobvious tapping patterns to metres. The tapping patterns they report for the metres match the measure boundaries introduced by Dehlavi (2000) and Azarsina (2017).

In this paper, I combine these observations (plus a few more) to establish an account of the Persian metrical system that assumes minimal theoretical tools beside universal tendencies already known to us through experiments on rhythm perception. Given the close similarity between the Persian system and other quantitative systems, such as Arabic and Greek, adopting this framework has important consequences for our analysis of these metrical systems as well. I discuss the advantages of this approach in the analysis of Arabic metres in a forthcoming paper.

The remainder of this paper is structured as follows. Section 2 provides an overview of the Persian metrical system, classifies the metres into four major classes and presents a list of the metre families that are to be accounted for. Section 3 lays out the theoretical foundations of the present approach, introduces the tapping patterns associated with the metres and shows how they can motivate our classification of the metres and help us divide them into constituents. Section 4 is where the Persian metre inventory is finally accounted for using a set of constraints. Section 5 compares the present approach and its results with previous theories of Persian metre. Finally, a short summary and conclusion is offered in the last section.

2. Classification and fragmentation

An example pair of verses from a classical Persian poem is presented in Example (1). The string of L and H symbols to which the verse is mapped is shown above it. I refer to an abstract string of this form as a 'SYLLABLE SEQUENCE'. Syllable boundaries within words are shown with dots.

The rules governing the correspondence between the linguistic content and the syllable sequence have been identified and described in detail in the literature (e.g. Hayes 1979, Thiesen 1982, Shamisa 2004). In short, light (monomoraic) and heavy (bimoraic) syllables are represented as L and H, respectively, and superheavy (trimoraic) syllables are treated as equivalent to HL verse-medially. All syllable forms are treated as H verse-finally.

(1)

LH	L	H	LL	HH	LHL	HH	H
bi.ā	ke	bā	sa.r-e	zol.f-at	qa.rār	khā.ham	kard
come	that	with	head-of	hair-your	pledge	I.will	do

'Come! I make a pledge with the tip of your hair'

L	H	LH	LLH	HLHLH	LLH
ke	gar	sa.r-am	be.ra.vad	bar.na.dā.ra.m-az	qa.da.m-at
that	if	head-my	goes.SBJV	I.do.not.remove-from	foot-your

'That if I lose my head, I do not remove my head from your feet'

Hafez, GHAZAL 89: couplet 5 (Khanlari 1983)

The rules determining what syllable sequences a given verse may be mapped to are largely governed by the phonology of the formal register of Persian. For the sake of simplicity of analysis and following previous researchers, in this study, I treat the process that replaces superheavy syllables in the manner described above and treats the final syllable as an H as part of the phonological apparatus too (i.e. assume a conventionally modified poetic phonology; see Hayes Hayes 1988 and the references therein). This decision seems acceptable given that there are no metres requiring superheavy syllables in any positions and, more importantly, the constraints governing metricality (see Section 4) apply to the derived sequence of L's and H's.[2]

[2] As Kiparsky (2018) points out, metrical systems in general never require a superheavy syllable in any part of a metrical pattern. It appears that any temporal pattern is first translated to one with

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The syllable sequences of the two verses in Example (1) are shown in Example (2), where each sequence is divided into smaller blocks separated by spaces for ease of reading.

(2) (a) LHLH LLHH LHLH HH
(b) LHLH LLHH LHLH LLH

These sequences, although slightly different, are considered close enough in the Persian metrical system to be used interchangeably in poetry. Such interchangeable forms usually are said to belong to the same 'metre'. A metre is therefore an abstract entity, as it may be represented via multiple syllable sequences. It is common to introduce each metre with a syllable sequence that is considered its unmarked form (or 'CANONICAL FORM') based on frequency and the regularity of the surface form. In this particular example, there is consensus that the canonical form is Example (2b). In this paper, I only focus on the structure of canonical forms of metres. For reasons that become clear in Section 4, I refrain from representing a metre as a sequence of metrical positions (see Halle 1970, Prince 1989), each of which may be realised as one of a limited set of syllabic configurations. Instead, a metrical position is any of the positions in the lowest level of the grid representation (corresponding to a mora rather than a syllable or a sequence of syllables), as explained in the following sections.

A syllable sequence may have multiple well-formed metrical analyses (i.e. it can be legally aligned with more than one accent hierarchy). In principle, we must treat these different metrical analyses as different metres if we want to be able to classify 'metres' based on their metrical properties (as we do below). This would mean that the syllable sequence of the canonical form is not sufficient for introducing a metre; the metrical structure (i.e. the accent hierarchy) is required too. However, to avoid additional terminological complexity and to conform to already established practices, I refer to structureless syllable sequences like the one in Example (2b), which constitute the common representation of metres in popular 'metre lists', as metres. In practice, this does not pose a serious problem as factoring out a few exceptions, each of these syllable sequences has exactly one dominant metrical analysis.

2.1. *The four classes of Persian metres*

In speaking of the Persian metrical system, I refer to the productive system of intuitions possessed by participants, rather than the existing repertoire of attested metrical patterns. In this system, innovative metres are introduced occasionally and speakers agree on how metrical these unfamiliar patterns are to them.[3] In practice, however, I follow the lead of previous researchers in focusing only on the

inter-onset intervals that have 1:2 duration ratios. This may be related to a universal tendency towards allowing only two duration categories (with a 1:2 duration ratio) in rhythmic patterns (Krumhansl 2000).

[3] Shamisa (2004: pp. 10–14) names four examples of such innovations in recent times.

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finite set of metres attested in corpora. As a relatively fixed source reflecting the metricality judgments of poets, they can serve as a reliable common reference point.

Hayes's (1979) account of Persian metres is arguably the most compelling among existing works. Relying on the data and initial analysis provided by Elwell-Sutton (1976), he identifies three classes of Persian metres. Published in 1979, his work does not explicitly mention moras, yet it effectively introduces three distinct classes of Persian metres with 5-, 6- and 7-mora constituents. For instance, HLH is a 5-mora constituent, as its syllables have 2, 1 and 2 moras, respectively. However, his account misses an entire class of Persian metres, that is, the relatively less common class of metres composed of 4-mora constituents. A more recent analysis by Deo & Kiparsky (2011) covers this class, explicitly pointing out that it is based on 4-mora constituents. Overall, this results in four classes of Persian metres; I refer to them as 4-, 5-, 6- and 7-based metres. Other scholars such as Jali (1993) have already independently argued for such a 4-class division and – in line with what this paper is going to argue for – mapped the four classes to four musical time signatures (more on this in Section 3).

In addition to metre classes, it is useful to define another term to denote collections of metres. Following Khanlari (1948) and as a preliminary definition, I consider two metres m_1 and m_2 to belong to the same 'METRE FAMILY' if one is an initial substring of the other. Thus, for instance, 'HLLH HLLH' and 'HLLH HLLH H' count as belonging to the same family since the former is an initial substring of the latter (this definition for metre families is revised in Section 3 after constituents are formally defined).

I take the metre families Hayes (1979) accounts for as a starting point. To fill the gaps in his list, I add to it every metre family that appears more than twice in Parhizi's (2002) corpus (his corpus contains nearly 45,000 poems; Elwell-Sutton's contains around 20,000) and does not contain caesuras.[4] This combination, which constitutes the entire set of metre families I shall account for, is presented in Table 1. Metre families not directly accounted for in Hayes's analysis have an underlined row id in the table. The rightmost column shows the frequency of each metre family in Elwell-Sutton's corpus.

The dashes reflect Hayes's fragmentation of the metres into constituents, and in the case of those not discussed by Hayes, they are discussed by Parhizi. The fragmentations eventually proposed in this paper are different in many cases. In the table, no dashes are used for constituent boundaries that would not match a syllable boundary (i.e. those falling between the two moras of an H syllable), for example, between the first and second 6-mora halves of LLHLHLHH in row 22.

[4] In the context of Persian metres, caesuras are identified as boundaries (typically accompanied with pauses during recitation) in the middle of verses in certain metres. As Najafi (2015) shows, caesuras behave exactly like verse endings as far as metrical considerations are concerned. Metres with caesuras – which are used in less than 2% of the poems appearing in corpora – in many cases involve the use of an H in place of an expected L as the first syllable of the verse; a topic I do not discuss in this paper.

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Class		Metre family	Freq. %
4-based	1.	HH - LLH - HH - LLH - …	
	2.	HLL - HH - HLL - HH - …	
	3.	LHL - HH - LHL - HH - …	<0.1
	4.	LLH - LLH - …	
	5.	HLHLH - HLHLH - …	
5-based	6.	LHH - LHH - …	3.2
	7.	HLH - HLH - …	<0.1
6-based	8.	HLLH - HLLH …	1.2
	9.	HHLL - HHLL - …	7.3
	10.	LHH - LLHH - LLHH - …	0.1
	11.	LLHH - LLHH - …	11.2
	12.	LHLH - LHLH - …	<0.1
	13.	HLHL - HLHL - …	<0.1
	14.	LHLH - HLLH - LHLH - HLLH - …	<0.1
	15.	HLLH - LHLH - HLLH - LHLH - …	0.8
	16.	HLHL - HLLH - HLHL - HLLH - …	<0.1
	17.	HLLH - HLHL - HLLH - HLHL - …	2.7
	18.	LHLH - LLHH - LHLH - LLHH - …	15.9
	19.	LLHH - LHLH - LLHH - LHLH - …	9.0
	20.	HHLL - HLHL - HHLL - HLHL - …	3.9
	21.	HLHL - HHLL - HLHL - HHLL …	<0.1
	22.	LLHLHLHH - LLHLHLHH - …	0.6
	23.	HHLHLHLL - HHLHLHLL - …	16.1
7-based	24.	LHHH - LHHH - …	10.9
	25.	HLHH - HLHH - …	15.8
	26.	HHLH - HHLH - …	1.2
	27.	LLHLH - LLHLH - …	

Table 1
The metre families covered.

These boundaries are discussed in detail in Section 5. For row 10, Hayes suggests a silent mora in the beginning of the first metron (see Section 5).

I do not attempt to account for frequency differences between these metre families, as usage frequency is affected by important factors beside metrical well-formedness, including genres and historical trends, practical concerns regarding the syllable structure of words[5] and most importantly, rhythmic concerns that do not match well-formedness preferences. Regarding the last point, note that for instance, 4-based metres are found perfectly well formed (perhaps even more than all 7-based metres), but the poetic tradition seems to often find them too ‘sing-songy’ to be suitable for serious poetry (on the deliberate use of metrical complexity as an aesthetic tool in poetry, see Fabb & Halle 2006). Thus, the ideal method of measuring degrees of metrical well formedness (in the narrow, rhythm-oriented,

[5] For instance, the metre families of rows 12 and 13 in Table 1 are particularly limiting since they do not allow any words with LL or HH sequences.

sense) in Persian seems to be conducting experiments involving participants rather than consulting corpus frequencies. In any case, existing theories of Persian metrics generally do not account for frequency differences between metre families either.[6]

3. Metrical structure

A central argument of the present paper is that like metre in music, metre in Persian poetry relies on accents. Accent in this context is entirely different from linguistic stress; it corresponds to what Lerdahl & Jackendoff (1983), henceforth GTTM, call ‘metrical accents’ in music. These accents are assigned by the listener to certain positions in a musical piece.

The simplest method for finding the positions of the accents is to ask participants to tap to the rhythm as they read a poem aloud or listen to it. For the arguments of the present study to be compelling, it is critical to establish that these tapping patterns do not merely reflect an independent ‘text-setting’ tradition secondary to actual metrical appreciation. Thus, a closer examination of what ‘text-setting’ amounts to in this context is in order.

I follow the common practice, explicitly formulated by Kiparsky (2006), of treating linguistic content, poetic metrical structure and musical rhythm as three distinct entities, where a scansion is an alignment between linguistic content and poetic metrical structure, while text-setting involves the alignment of linguistic content with musical rhythm (for a different approach, see Hayes & Kaun 1996: p. 247).

Persian poetry is a ‘spoken’ poetic tradition and is in fact enjoyed primarily through silent reading. Normally, when recited, it does not sound like chanting. Nevertheless, if the reciter recites the verses faster than usual, pronounces the syllables with durations proportional to their moraic lengths (a relatively ‘natural’ practice, given the nature of moras as mental time units)[7] and avoids the verse-medial pauses that are common at syntactic boundaries during normal recitation, the resulting recitation resembles chanting; it is isochronous and can be accompanied by tapping.[8]

This manner of reading Persian poetry is often considered somewhat frivolous and is used mostly either for enhanced aesthetic pleasure or (less frequently) to help novices perceive the metrical nature of the verses. I refer to the way participants in the tradition assign rhythm to this form of recitation (manifested through their tapping patterns) as the syllable sequence’s ‘natural text-setting’. Even though it is a text-setting instance rather than a scansion, I argue that a syllable sequence’s natural

[6] The only exception is that Hayes does account for the low frequencies of the metre families of rows 12 and 13 (but not those of rows 7, 14, 16 and 21).

[7] This does not occur in ordinary speech though. It has been reported in other languages, such as Japanese and Arabic as well that the proportions of the syllables’ actual durations generally do not reflect their moraic lengths in ordinary speech (Port et al. 1980).

[8] In the case of metres that require verse-final pauses, the gap between recitation and chanting is slightly wider (see below).

text-setting is special in that it reflects the scansion by virtue of which the syllable sequence is deemed metrical in the first place. The tapping patterns speakers assign to metres in the experiment by Mirzaee et al. (2019) (where subjects read the poems aloud and tap while reading, in the absence of melody) reflect these natural text-settings.

In most melodic performances where the verses are in fact 'sung', such as those of the *nowhe* ceremonies introduced later in the article, the same natural text-setting is used. However, it is readily possible to arrive at a text-setting other than the natural text-setting for a metre. This can trivially be achieved through an ill-formed alignment where the grid structure is not a good fit for the temporal pattern, or, more conveniently, through giving the syllables durations that do not reflect their moraic lengths, thereby achieving an alternative temporal pattern. The latter case is what happens in Tashlhiyt Berber songs, as explained below.

Dell & Elmedlaoui (2008) report that each Tashlhiyt Berber song is associated with a specific tapping pattern. Crucially, I argue that this tapping tradition is fundamentally different from what we have at hand in the case of Persian. There are two important elements in Berber songs demonstrating that the tapping patterns Dell and Elmedlaoui talk about reflect a specific text-setting tradition rather than directly reflecting the scansions that are responsible for making the verses metrical in the first place. First, the tapping patterns in the Tashlhiyt Berber tradition belong to the 'sung' versions of the songs. As Dell & Elmedlaoui (2008) state, 'when TB speakers remember a line of poetry, they also remember the tune to which the line was sung when they heard it'. (p. 23) Second, and more importantly, inter-onset intervals do not correspond to the moraic lengths in the sung versions of the the Tashlhiyt Berber songs. Light and heavy syllables are quite frequently sung with different lengths, resulting in temporal patterns that surely cannot count as having a one-to-one and direct relationship with the syllable sequences.

In Persian, the situation is entirely different. Most participants never hear melodic compositions of many of the metres in their lives. Yet, a fluent participant of the Persian metrical tradition can easily find the tapping pattern of a metrical poem (especially if it belongs to the rhythmically simpler 4-based and 6-based classes) upon hearing it or even simply reading it in silence. The participants' knowledge of the phonological system of the language enables them to reconstruct the idealised syllable lengths and thereby the appropriate metrical accent hierarchy in their mind and appreciate the poem's metrical harmony even in the absence of an overt isochronous auditory input. In fact, metrical poetry in Persian has no metrical structure other than the one assigned to it by the listener by virtue of its correspondence to a temporal pattern.

One might argue that even though each Persian metre has its own specific tapping patterns, these tapping patterns may still not reflect the metrical structure of the poetic metres. But where do these tapping patterns come from according to such a view? If we hold the listeners' musical intuitions responsible for naturally assigning them to temporal patterns, we must answer why every Persian metre happens to correspond to a temporal pattern that induces tapping. Note that it is unlikely for a randomly generated temporal pattern to sound 'rhythmic' and readily induce tapping. Thus, we must accept that only syllable sequences that are found rhythmic by the listeners' musical intuitions and induce tapping patterns are accepted as metrical in Persian, thereby virtually accepting the present paper's main proposal.

If, on the other hand, we wish to attribute the tapping patterns to an independent, 'artificial' system learned by the participants separately (similar to the Berber case), we face practical problems. Persian speakers simply do not hear enough poems of diverse metres chanted (with or without taps) in their lifetime to be able to learn such patterns through exposure. For instance, 4-based metres are so rare that they are missed almost entirely in Elwell-Sutton's corpus and appear less than 80 times in total in Parhizi's (2002) corpus of more than 45,000 poems (i.e. less than 0.2%). Yet, even though their tapping patterns are clearly different from any of the other metre classes, participants have no problem tapping to poems in these rare metres. Azarsina (2017: p. 42) reports that 6- to 8-year-old schoolchildren have no difficulty tapping at the right points when hearing poems of different metre families. Shapurian (1999) recounts an interesting story of how a renowned contemporary poet (Mehdi Hamidi) recited a new poem of his in a school classroom and found the students tapping their feet along with the rhythm. Interestingly, the poem in question has an extremely rare 4-based metre family ('LLH-HH…') with no well-known precedents and is absent from our list in Table 1.

The correspondence between syllable onsets (or the beginnings of syllable nuclei) and musical events is well known in other musical traditions as well (e.g. Dell & Elmedlaoui 2008, Dell & Halle 2009). In the particular case of Persian, this, along with the general correspondence between syllable sequences and temporal patterns, has been established through an experiment by Bouban (2013), where it is shown that Persian speakers are able to discern the corresponding syllable sequence upon hearing a temporal pattern produced using a percussion instrument, aligning musical events with syllable onsets (or the beginnings of the syllable nuclei).

Finally, the attitude of the participants towards the relationship between musical and poetic metre must also be taken into account. For a participant of the tradition, metricality judgments can hardly be decoupled from the sense of rhythmic appreciation that induces the tapping. Contemporary Persian poet and literary critic Parviz Khanlari is quoted (Elahi 1997: p. 128) saying that the criterion for determining metricality is the *tombak* (a traditional Iranian drum-like instrument). It was already mentioned that the correspondence between syllable sequences and temporal patterns has been acknowledged by Persian metricists since as early as the 13th century CE.

The tapping data provided here for individual metre families are based on four sources: the metrical judgments of the author and two consultants who are competent participants in the poetic tradition with experience in composing metrical poetry, a list of tapping patterns for 50 metres reported by Mirzaee et al. (2019)

based on experiments on a group of participants,[9] the musical fragmentations offered by Azarsina (2017) and, finally, recordings of traditional ceremonies that involve melodic performances accompanied by (mostly spontaneous) tapping or beating. The recordings, collected for the purpose of this research, are available along with transcriptions and tapping pattern annotations online at the address http://www.persianmeters.com.

3.1. *Hierarchy of accents*

I use the standard method for the representation of metrical accents, that is, the metrical grid (Liberman 1975, Lerdahl & Jackendoff 1983, Prince 1983). Without further ado, let us look at an example. The accent pattern of a 4-based metre is presented in Example (3).

```
(3) *       *       *       *
    *   *   *   *   *   *   *   *
    * * * * * * * * * * * * * * * *
    ********************************
    LLH LLH LLH LLH LLH LLH LLH LLH
```

In this representation, each row of asterisks can be seen as an appropriate tapping pattern. Together, they show the accent structure. The syllable pattern is placed under the accent hierarchy, such that each asterisk in the lowest level corresponds to the beginning of a mora in the syllable sequence. A space is placed after every H syllable, representing the extra mora. The asterisks in the lowest row are our metrical positions. In each row, an asterisk means that a tap is expected AT THE BEGINNING of the mora it represents in the corresponding tapping pattern. The lowest row, for instance, represents the fastest tapping pattern appropriate for this metrical form, where the beginning of each mora receives a tap. A position with more asterisks above it is said to have a stronger accent. It is worth noting that all of the metres we call 4-based have identical tapping patterns. The shared tapping pattern between different 4-based metres supports our decision to place them in the same class.

The correspondence between the accent structure observed here and metre in music is straightforward. A mora corresponds to the distance between two consecutive pulses (i.e. two consecutive asterisks at the lowest level) and syllable onsets (or the beginnings of syllable nuclei) correspond to musical events. The metre here corresponds to a simple metre in music, and if we take moras as equal to eighth notes, each 8-mora sequence starting with a maximally strong event can be taken to correspond to a musical measure in a $\frac{4}{4}$ time signature. The measure-initial strong events count as 'downbeats'.

[9] Mirzaee et al. (2019) only report colon-level taps for 4-based metres and metron-level taps for other metres (to be explained below).

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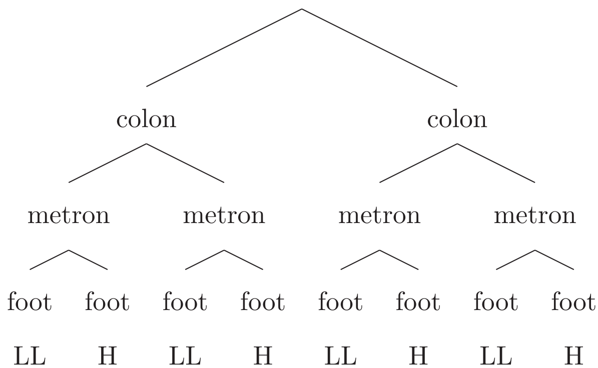
We can use these accent patterns to devise a hierarchical constituent structure. Inspired by the way units, such as measures and beats, are generally identified in music, I propose that metrical structures are composed of hierarchies of constituents, such that in each metrical constituent, the first position has the strongest metrical accent.[10] Building upon this hypothesis, which we may call the 'head-initiality hypothesis', a unique tree with binary branching can be created for each metrical grid. The corresponding tree structure for the metre in Example (3) is shown in Example (4). I call the constituents at the lowest level of the hierarchy 'FEET', and the ones above them 'METRA' (singular: 'metron') and 'COLA' (singular: 'colon'), respectively. The tree and the grid express the same information regarding the accent hierarchy, although they have different theoretical implications that are not our concern here. In what follows, I generally use tree terminology to refer to different parts of a metrical form and use grids for showing actual accent patterns. It is worth noting that even though technically one may count single moras as constituents below the foot level, for simplicity, I use the term 'constituent' only to refer to feet and units above it in the metrical hierarchy.

(4)



3.2. *Accents and metre classes*

So far, we have shown that similarity of tapping patterns motivates classifying a group of Persian metres together, all of which can be viewed as having 4-mora metra. We refer to these metres as 4-based metres. A tendency towards repetition at the level of cola leads to all such metres having 8-mora repetition cycles.

In 6-based metres, the rhythm is compound: the asterisks are three moras apart in the second row from below, meaning that the feet have three moras each (instead of two). The tapping patterns associated with one such metre (based on alternations of HLLH and LHLH) is presented in Example (5). Compound (i.e. ternary) metre is far more popular than simple metre in Persian poetry. This fits well with the

[10] The constituents we talk about here are metrical structures and must not be confused with Lerdahl and Jackendoff's (1983) 'groups', which are constituents that are defined independently of metrical structure although they interact with it.

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observation that Persian music is overwhelmingly dominated by rhythms with compound time signatures (Farhat 2004: p. 115).

(5)
```
*                       *
*           *           *           *
*     *     *     *     *     *     *   *
* * * * * * * * * * * * * * * * * * * * * * *
H  LLH      LH    LH    H   LLH     LHLH
```

The case of 5- and 7-based metres (henceforth ‘odd’ metres, as opposed to ‘even’ metres) is slightly more complicated. In these metres, the metron cannot be divided into two equal halves. The accent pattern of a 7-based metre based on repetitions of HHLH is shown in Example (6).

(6)
```
*                           *
*             *             *             *
*       *     *       *     *       *     *       *
* * * * * * * * * * * * * * * * * * * * * * * * * * * *
H   H   LH    H   H   LH    H   H   LH    H   H   LH
```

Note that the asterisks at the second level in this metre are not equidistant. In each metron, the first foot has four moras, while the second one has three. This goes against the metrical well-formedness criteria introduced by Lerdahl & Jackend (1983: p. 69), according to which the distance between asterisks in level n must be two or three (not four) asterisks in level $n-1$. However, as argued in GTTM (p. 97), and highlighted by London (2004: p. 103), this constraint only applies to classical Western tonal music and may be dropped in other traditions. The tapping patterns associated with 7-based metres such as this one show that the grid in Example (6) is indeed the correct grid (e.g. compare recordings 43 and 46 in the online database).

The same asymmetry is visible in 5-based metres. An example is shown in Example (7).

(7)
```
*                   *
*         *         *         *
*     *   *     *   *     *   *     *
* * * * * * * * * * * * * * * * * * * *
H   LH    H   LH    H   LH    H   LH
```

In this and other 5-based metres, the two feet in a metron are two and three moras long. We may argue that odd metres are generally less well formed because of their nonisochronous nature. This lower degree of well formedness seems to be responsible for the fact that repetition is typically observed more steadfastly (i.e. observed at the level of metra rather than cola) in these metres, resulting in the absence of metre families of cycle lengths 10 or 14 in the list of common Persian metres.

3.3. *Anacrusis*

So far, we have seen accent hierarchies that support a 4-class division of Persian metres and the idea of treating the metres as temporal patterns. Moreover, we used these accents to establish a constituent structure for the metres based on the head-initiality hypothesis. It is now time to see cases where the head-initiality hypothesis results in fragmentations completely different from those given in Table 1.

All major existing accounts of the Persian metre inventory divide a metre into constituents following a 'left-to-right' procedure. They start from the left side of the metre and count full constituents moving rightward. If necessary, they assume an incomplete constituent at the right edge. The typical fragmentation of a metre from the family 'HHLLHH…' under these theories is shown in Example (8).

(8) HHLL - HHLL - HHLL - HH

However, in this metre, the first tap at the metron level falls at the beginning of the SECOND syllable. Therefore, fragmenting the metre based on the head-initiality hypothesis yields a different result. The tapping pattern and the fragmentation induced by it are shown in Example (9).

(9)

```
          *                         *
          *            *            *            *
          *    *       *    *       *    *       *
 * *      * * * * * *  * * * * * *  * * * * * *  * *
 H     -  H   LLH   -  H   LLH   -  H   LLH   -  H
```

Incomplete initial metra, such as the initial H in Example (9) correspond to pickup notes or anacruses (singular: anacrusis) in music. I use the latter term for them in this context too. I refer to incomplete metra at the end of metres (such as the final H in Example (9)) as 'complements'.

To give a clearer picture of the structure of this metre, it is useful to present an annotated version of a performance of a poem in this metre (recording 10 in the online database). This performance involves singing and is therefore not an instance of the natural melody-free chanting style discussed earlier. However, its rhythmic structure is the same as that of the text-setting corresponding to the natural chanting style. In this and similar performances, which belong to Shia Muslim religious mourning ceremonies (known as 'NOWHE'), it is part of the tradition for the audience to beat on their chests along with the rhythm of the poem sung by the main performer. An asterisk above a syllable in Example (10) denotes a beating action at its onset. The duration of each metron is measured (in seconds) and shown on the third line of the gloss for each verse. The μ signs indicate missing moras in the metre that are realised as pauses (more on this below).

(10)

*	*			*	*	
H)(H	LLH)(H	LL	H)	(HL	LH)(H	$\mu\mu$
jen.nō	ma.la.k-em.shab	ha.me	bar	sī.ne	za.nā.nand	
)(1.43	)(1.42		)	(1.49	)(1.41	

	*		*		*	*	
H)	(HL	L	H)(H	LL	H)(HL	LH)(H	$\mu\mu$
dar	nā.le	o	zā.rī	ha.me	osh.shā.gho	jo.nā.nand	
)	(1.36		)(1.33		)(1.39	)(1.46	

*		*		*	*	
H)(H	LLH)	(H	LL	H)(H	LLH)(H	$\mu\mu$
ā.hē	ha.me.gī	tā	sa.re	key.van	bo.va.d-em.shab	
)(1.44	)	(1.39		)(1.36	)(1.46	

	*	*	*	*	
H)	(HLLH)	(HL	LH)(H	LLH)(H	$\mu\mu$
dar	kar.bo.ba.lā	shā.me	gha.rī.ban	bo.va.d-em.shab	
)	(1.35)	(1.35	)(1.49	)(	

JINNS AND ANGELS ARE ALL BEATING ON THEIR CHESTS TONIGHT
WEEPING AND MOANING, THEY ARE LIKE LOVERS AND LUNATICS
THEIR LOUD SIGHS CAN BE HEARD IN SATURN TOO.
TONIGHT, IT IS THE NIGHT OF THE FORSAKEN IN KARBALA

The taps occur once per metron (for performances with foot-level and colon-level tapping on the same metre family, see recordings 34 and 35 in the online database). The total length of the metre (22 moras) is not a multiple of the length of a full metron (six moras). The pauses occur in such metres to make up for the missing moras[11] and correspond to musical rests. A similar phenomenon is observed in Japanese (Asano 2000, Cole & Miyashita 2006) and Hausa (Kiparsky 2018) metrical poetry. The pause lengths measured in this recording confirm this; the lengths of the metra that include pauses are within the same range as the other ones (they are all between 1.33 and 1.49 seconds long), suggesting that the pauses are two moras long. Measurements for other recordings in the database show similar results.

We may now revise our definition of 'metre family'. Let us call a set of metres composed of the same metra (under the present theory), starting with the same metron and having the same anacrustic syllables (if any) a 'metre family'. Analysing metre structure based on the head-initiality hypothesis establishes interesting connections between metre families. The metre families in Table 2, for instance, are all based on the metron HLLH. The conventional left-to-right fragmentation method misses this generalisation, treating these metre families as composed of unrelated metra.

[11] In some cases, instead of making a pause, the performer lengthens the final syllable.

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	Family
1.	HLLH - HLLH - HLLH - HLLH - …
2.	LLH - HLLH - HLLH - HLLH - …
3.	LH - HLLH - HLLH - HLLH - …
4.	H - HLLH - HLLH - HLLH - …

Table 2
Metre families based on HLLH.

Interestingly, the relationship between these metre families emerges (although partially) in poetic practices too. They are considered so similar that they are sometimes used in different lines of the same work in less formal genres of poetry. The famous poem sung in recording 45 in the online database has lines starting with metre families of both rows 3 and 4. Similarly, in the genre known as BAHR-E TAVĪL (not a sung genre),[12] using lines with metres of rows 2 and 3 together is relatively common.[13]

This concludes our discussion of anacrusis. I end this section by repeating the list of the metre families this paper aims to account for in Table 3 (the same as the ones listed in Table 1), this time also presenting their (metron-level) tapping patterns and dividing them into metra based on the head-initiality hypothesis. This table contains the data that are to be accounted for through constraint interaction in the next section. In the case where a tap goes on the second mora in an H syllable (row 5), the two moras are shown as two ‘h’s. The three columns on the right indicate which of our three external sources confirm the tapping patterns reported by the author and the consultants. For syllable sequences that do not have one dominant metrical analysis (19 and 23), the competing forms are reported in separate rows.

4. Determining metricality

This section presents a set of weighted constraints based on the framework introduced so far to account for the Persian metre inventory. I limit the scope of the paper to metre families and do not discuss constraints that determine which potential metres within a metre family are more well formed (i.e. how many metra and which complements are ideal).

In any metrical system, a distinction can be made between the output of phonological analysis and the metrical analysis (or ‘scansion’) of this output. The scansion is ‘assigned’ to the phonological output. English metre, for instance,

[12] Not in any way related to the Arabic ṬAWĪL metre family in spite of the similarity in name.

[13] I introduce two relatively famous examples that are easy to find on the web (although available only in Persian). A BAHR-E TAVĪL by Nabati (2013: p. 20) starts some of the lines with ‘LLH - HLLH’ (e.g. ‘man-e bīchāre che sān sharh daham’) and several others with ‘LH - HLLH’ (e.g. ‘ajab gardan-e mīnā’, ‘biā ey del-e nādān). The second example is by Sazegar (2008), where most lines use ‘LLH - HLLH’, but the metre family switches to ‘LH - HLLH’ every time ‘manam horr-e gonahkār’ is repeated.

	Metre family	Online database	Mirzaee et al. 2019	Azarsina 2017
1.	$\overset{*}{\text{H}}$H - $\overset{*}{\text{L}}$LH - $\overset{*}{\text{H}}$H - $\overset{*}{\text{L}}$LH - …		✓	
2.	$\overset{*}{\text{H}}$LL - $\overset{*}{\text{H}}$H - $\overset{*}{\text{H}}$LL - $\overset{*}{\text{H}}$H - …			
3.	$\overset{*}{\text{L}}$HL - $\overset{*}{\text{H}}$H - $\overset{*}{\text{L}}$HL - $\overset{*}{\text{H}}$H - …	✓	✓	
4.	$\overset{*}{\text{L}}$LH - $\overset{*}{\text{L}}$LH - …	✓		
5.	$\overset{*}{\text{H}}$Lh $\overset{*}{\text{h}}$LH - $\overset{*}{\text{H}}$Lh $\overset{*}{\text{h}}$LH - …		✓	
6.	LH - $\overset{*}{\text{H}}$LH - …	✓	✓	✓
7.	$\overset{*}{\text{H}}$LH - $\overset{*}{\text{H}}$LH - …	✓	✓	
8.	$\overset{*}{\text{H}}$LLH - $\overset{*}{\text{H}}$LLH …	✓	✓	
9.	H - $\overset{*}{\text{H}}$LLH - $\overset{*}{\text{H}}$LLH - …	✓	✓	✓
10.	LH - $\overset{*}{\text{H}}$LLH - …	✓		✓
11.	LLH - $\overset{*}{\text{H}}$LLH - …	✓	✓	✓
12.	$\overset{*}{\text{L}}$HLH - $\overset{*}{\text{L}}$HLH - …	✓	✓	
13.	$\overset{*}{\text{H}}$LHL - $\overset{*}{\text{H}}$LHL - …			
14.	$\overset{*}{\text{L}}$HLH - $\overset{*}{\text{H}}$LLH - $\overset{*}{\text{L}}$HLH - $\overset{*}{\text{H}}$LLH - …			
15.	$\overset{*}{\text{H}}$LLH - $\overset{*}{\text{L}}$HLH - $\overset{*}{\text{H}}$LLH - $\overset{*}{\text{L}}$HLH - …	✓		
16.	$\overset{*}{\text{H}}$LHL - $\overset{*}{\text{H}}$LLH - $\overset{*}{\text{H}}$LHL - $\overset{*}{\text{H}}$LLH - …			
17.	$\overset{*}{\text{H}}$LLH - $\overset{*}{\text{H}}$LHL - $\overset{*}{\text{H}}$LLH - $\overset{*}{\text{H}}$LHL - …	✓	✓	
18.	$\overset{*}{\text{L}}$HLH - $\overset{*}{\text{L}}$LHH - $\overset{*}{\text{L}}$HLH - $\overset{*}{\text{L}}$LHH - …		✓	
19a.	$\overset{*}{\text{L}}$LHH - $\overset{*}{\text{L}}$HLH - $\overset{*}{\text{L}}$LHH - $\overset{*}{\text{L}}$HLH - …			
b.	LLH - $\overset{*}{\text{H}}$LHL - $\overset{*}{\text{H}}$LLH - …			✓
20.	H - $\overset{*}{\text{H}}$LLH - $\overset{*}{\text{L}}$HLH - $\overset{*}{\text{H}}$LLH - …	✓	✓	✓
21.	H - $\overset{*}{\text{L}}$HLH - $\overset{*}{\text{H}}$LLH - $\overset{*}{\text{L}}$HLH - …			
22.	LLH - $\overset{*}{\text{L}}$ HLH - $\overset{*}{\text{H}}$LLH - …	✓	✓	✓
23a.	HH - $\overset{*}{\text{L}}$HLH - $\overset{*}{\text{L}}$LHH - …		✓	
b.	H - $\overset{*}{\text{H}}$LHL - $\overset{*}{\text{H}}$LLH - …	✓		✓
24.	LH - $\overset{*}{\text{H}}$HLH - …	✓	✓	✓
25.	HLH - $\overset{*}{\text{H}}$HLH - …	✓	✓	✓
26.	$\overset{*}{\text{H}}$HLH - $\overset{*}{\text{H}}$HLH - …	✓	✓	✓
27.	$\overset{*}{\text{L}}$LHLH - $\overset{*}{\text{L}}$LHLH - …	✓	✓	✓

Table 3
List of metre families, their metron-level tapping patterns and sources confirming their tapping patterns.

tends to establish a one-to-one mapping between syllables and metrical positions, avoiding the assignment of weak positions to stress maxima. What we call a 'metrical pattern' in the English system is the abstract strength hierarchy, independent of how syllables are supposed to realise it. Now, consider the Persian metrical forms in Example (11). They have identical grid structures but different syllable sequences.

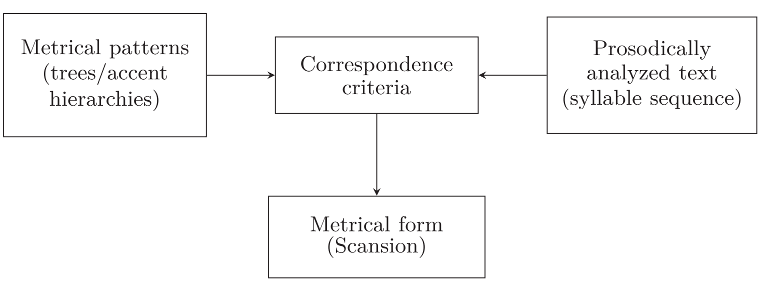
(11)

```
         *                             *
         *     *                       *     *
         *  *  *  *                    *  *  *  *
         * * * * * * * * * * *         * * * * * * * * * * *
(a)      H  LLH  LH  LH          (b)   H  LH  LH  LLH
```

In theory, we can treat each of the forms in Examples (11a) and (11b) as an independent metrical pattern. However, this would lead to missing the parallelism with stress-based systems, such as English. The alternative approach I adopt here is to define 'metrical pattern' as the strength hierarchy and to treat Examples (11a) and (11b) as two metrical forms with the same metrical pattern. Under this analysis, metrical positions are nothing but positions in the abstract metrical pattern that must be filled with the beginnings of moras. What the syllable sequence provides for this metrical pattern is how these moras are divided into syllables. In other words, the syllable sequence merely tells us which pulses bear musical events. Having clarified these issues, we can also fix the definition of the term 'metrical form' used rather loosely so far in the context of Persian metrical poetry as a syllable sequence that has been assigned a metrical pattern.

The approach described above is in line with Deo's (2007) treatment of various Sanskrit 'metres' as realisations of the same abstract metrical pattern and Kiparsky's (2018) general approach of shifting the responsibility of explaining metrical diversity to realisation strategies rather than metrical patterns. In Example (12), which is a modified version of Kiparsky's diagram, a schematic representation of this analysis of Persian metrics is offered.

(12)



To a line with a syllable sequence of the form 'HLLHLHLH', the correspondence criteria assign a metrical pattern (i.e. an accent hierarchy) that results in a metrical

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	simple metre	compound metre
Normal:	4-based	6-based
Augmented:	5-based	7-based

Table 4
The four classes of metres.

analysis of the type shown in Example (11a). The same metrical pattern is allowed to be assigned to the syllable sequence 'HLHLHLLH', as demonstrated in Example (11b). The Persian metrical tradition happens to treat these two metrical forms differently enough to disallow their interchangeable use, leading us to refer to them as belonging to different metres. One could argue that the process that decides whether two metrical forms could be used interchangeably or not (e.g. see the case of LL/H alternation in Example (1)) constitutes less a component of the metrical system per se and more part of the poetic tradition.

In formulating the requirements that determine whether a metrical form is well formed or not, we can make a distinction between three components:

1. The well formedness of the abstract metrical pattern (the tree)
2. The well formedness of the syllable sequence
3. The appropriateness of assigning the tree structure to the syllable sequence

Of these, the first two are governed by relatively simple criteria and are reviewed briefly here. The constraints governing the third item are discussed in the subsections that follow.

I have already informally discussed what constitutes a well-formed metrical pattern (i.e. a well-formed tree). To formulate the requirements more formally, I discuss the trees for even and odd metres separately. For even metres, the tree must have binary branching with feet that have the same number of mora slots (either two or three). One can optionally augment one mora per metron in a tree of this form to achieve a well-formed tree for an odd metre. The relationship between the four major Persian metre classes is depicted in Table 4.

The well-formedness requirements for the syllable sequence are even simpler to describe. The only constraint known in the literature is one prohibiting LLL sequences (Shamisa 2004). It is inviolable and has parallels in Arabic and Ancient Greek too (Prince 1989, Golston & Riad 2000, Steriade 2017). In addition to this, I propose that the constraint against HHH syllable sequences argued by Steriade (2017) to be active in Greek phonology plays a role in Persian metrics, even though, unlike *LLL, it is violable.

4.1. *Assigning structure to syllable sequences*

The third – and most important – factor determining the well formedness of a metrical form is the appropriateness of the assignment of the tree to the syllable sequence. The criteria governing this assignment can be modeled as the interaction of metrical constraints. The constraint interaction scheme I propose is different from classical Optimality Theory (Prince & Smolensky 1993) in at least two ways. First, the constraints are weighted, with a clear 'gang-up' effect as in Harmonic Grammar (Legendre et al. 1990, Prince & Smolensky 1993). Second, the constraints are not meant to select an optimal output for a single input form. Instead, they assign well-formedness scores to independent metrical forms. This is similar to how MaxEnt grammars are used by Hayes & Wilson (2008) and Hayes et al. (2012) to compare items in a lexicon and an inventory of metrical forms, respectively. Since we are interested only in the ranking of the metrical forms rather than their actual relative well-formedness scores, we can simply compare the sums of weighted constraint violation scores, doing away with logarithmic scaling and the rest of the MaxEnt machinery. I present a few relatively simple constraints with tentatively suggested weights and assume a simple summation function for calculating the cumulative effect of the violations, aiming to account for the metrical forms presented in Table 3 as the only forms meeting certain thresholds.

If Persian metre perception is a special case of general rhythm perception, we expect the constraints that determine metricality to be the same as the general constraints governing rhythm perception in humans. The diversity observed among different quantitative metrical traditions is then to be explained via different weight assignments to the same set of universal constraints, similar to how we may understand cross-cultural differences in musical preferences.

Theoretical works that have attempted to present formal accounts of musical preferences, for example, those of GTTM and London (2004), do not go into much detail regarding what constitutes a well-formed metrical form. GTTM, for instance, presents an almost comprehensive account of what makes an accent hierarchy well formed (loosely corresponding to our tree well-formedness rules) through what it calls 'Metrical Well-Formedness Rules', but their 'Metrical Preference Rules', which discuss the correspondence between a presented musical surface and the accent hierarchy assigned to it, are hardly adequate for our purposes. I take GTTM's account as a starting point and look elsewhere for hints pointing to more subtle musical preferences.

Perhaps the most intuitive rule concerning metrical correspondence is what GTTM presents as a preference for the inception of musical events (corresponding to our syllable onsets) to be in metrically strong positions (p. 76). In GTTM, where these rules are supposed to decide which accent hierarchy to assign to a given musical surface (corresponding to a given syllable sequence), this rule is practically no different from its reverse formulation: a preference for strong metrical positions to align with musical events. For our purposes, however, since we wish to be able to compare well formedness among different metrical forms with different syllable sequences, the reverse formulation has different consequences and is indeed preferred.

According to this formulation, the 6-mora metron HLLH is superior to HHH. If we denote musical events with vertical lines and empty pulses with dots, the two

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correspond to '|.|||.' and '|.|.|.', respectively. The second foot in the metron starts with a vertical line in the latter but with a dot in the former, therefore making the former more well formed under our proposal. A parallel formulation is used by Povel & Essens (1985). In their account of metre assignment to temporal patterns, they punish the assignment of accents to empty pulses. A translation of this constraint in the language of syllables and metrical constituents is presented below.

ALIGNSYLLABLE: Metrical constituent boundaries must fall on syllable boundaries.

Let us now move to more subtle constraints. According to GTTM (p. 84), strong metrical positions tend to be aligned with the inception of long notes. This translates to a preference for feet and metra beginning with H syllables and in fact matches linguists' long-standing practice of associating H syllables with strong positions. However, this does not constitute the full picture, as explained below.

Povel and Essens present a more detailed formula, disfavouring accents that fall anywhere other than positions of the following three types:

1. Isolated events (i.e. events preceded and followed by silent pulses)
2. The first and last events in a cluster of more than two events.
3. The second event in a cluster of two events.

In essence, this requires accents to be on events that are preceded or followed by silences, with the qualification that in clusters of two events, only the second one is favoured to have an accent. Putting the qualification regarding clusters of two consecutive musical events aside (this tendency seems to have a very weak role if any in Persian metrics), we may capture the essence of the first two conditions in our own terminology as follows. H syllables attract two types of metrical positions: the beginning of a metrical constituent and its end. The second part of this statement is where we diverge from GTTM's account and the common practice of associating H syllables with strong metrical positions.

Given its importance for our analysis, it is worth mentioning that the tendency for long inter-onset intervals in temporal patterns (corresponding to heavy syllables in our analysis) to precede strong metrical positions (corresponding to the end of metrical constituents in our analysis), along with its mirroring tendency described above, is well known in the literature on the psychology of rhythm (see Povel & Okkerman 1981, Parncutt 1994 and references cited therein). As Grube & Griffiths (2009) put it, 'the basis of existing theories of temporal accent induction is the repeatedly reported behavioural finding of perceptual accentuations of tones that are followed and/or preceded by relatively long (silent) inter-onset intervals'.

Finally, note must be taken of the fact that neither of the two tendencies discussed above are either analogous or in conflict with the iambic–trochaic law well known among linguists. The iambic–trochaic law (Hayes 1985) concerns how listeners group musical events together, stating that in a sequence of musical events with alternating short and long inter-onset intervals, listeners tend towards iambic grouping. This is distinct from where metrical accents are placed, as demonstrated in Hayes's example 5 (for a detailed account of the distinction between grouping and metrical structure, see GTTM).

It is now time to formalise our constraints regarding H syllables. As before, since we are interested in comparing different metrical forms with different syllable sequences (rather than different trees for a given syllable sequence), the direction of the tendency makes a difference for us. Here again, I suggest that not only H syllables attract the aforementioned metrical positions, but those positions require H syllables as well. It is the latter tendency that is of interest to us and is captured by the following two constraints.

H-INITIAL: The first syllable in a constituent must be H.
H-FINAL: The last syllable in a constituent must be H.

My goal in the remainder of this section is to use these constraints (and a few less impactful ones to be presented later) to account for the Persian metre inventory. In the following subsections, I discuss the four classes of metres one by one, beginning with 4-based metres.

4.2. *4-based metres*

The effect of the three constraints introduced above is stronger on higher-level constituents. This is not surprising given the fact that a colon boundary, for instance, is a metron boundary and a foot boundary too. In 4-based metres, the colon is the lowest level in the hierarchy where most constraints have a visible effect. The only exception is that the ALIGNSYLLABLE constraint seems to affect metron boundaries too, although it is violable (see row 5 in Table 5 below).

We can use our constraints to determine the most well-formed 8-mora cola. In getting from the well-formed cola to the well-formed metres, two points must be kept in mind. First, due to a tendency towards repetition, there are no common 4-based metres (and in fact no common Persian metres in general) in which two different cola occur. Second, Persian metrics seems to generally disfavour anacrustic 4-based metres. These two facts together mean that there is a one-to-one mapping between cola and metre families in 4-based metres. Thus, Table 5 for well-formed 4-based cola corresponds to a list of well-formed 4-based Persian metre families.

Table 5 contains all possible 8-mora cola that do not induce the illegal LLL sequence and calculates violations of any of the three correspondence constraints, as well as the *HHH constraint on syllable sequences. Violations of the latter constraint are counted based on how many HHH sequences occur if the colon is repeated twice (this is to account for cases where HHH emerges only in repetition). The symbol '*c*' indicates that constraint violations at the colon level are concerned, similarly, '*m*' indicates the metron level. Each asterisk marks a violation.

The goal here is not to find the exact weights but to demonstrate how a fixed weight assignment for the constraints can account for all the Persian metres in

Colon	H-FINAL *c* w=4	ALGSYL *m* w=3	H-INITIAL *c* w=2	*HHH w=1	Sum
1. HH – LLH				*	1
2. HLL – HH				*	1
3. LHL – HH			*		2
4. LLH – LLH			*		2
5. HLHLH		*			3
6. LLH – HH			*	**	4
7. HLL – HLL	*				4
8. HH – LHL	*				4
9. LHHLH		*	*		5
10. LHL – LHL	*		*		6
11. HH – HLL	*		*	**	6
12. HH – HH				******	6
13. HLHHL	*	*			7

Table 5
4-based cola ranked in order of well formedness.

Table 3. I propose the weights 4, 3 and 2 for the three correspondence constraints and 1 for *HHH, arguing that these weights can account for the distribution of metra not only in 4-based cola but throughout the entire metrical system.

The weighted sum of violations can be viewed as a negative well-formedness score. The metre families shaded in gray are not attested in Parhizi's corpus and are not part of the set we wish to cover. It is clear from the table that the constraints successfully account for the desired metre families. Note, however, that the shaded metre families (except perhaps the last row) are also found at least marginally metrical by the author and the consultants.

4.3. *Simple 6-based metres*

We may now use the same set of constraints and weights to rank well-formed constituents in 6-based metres. In these metres (and in fact any metre class other than 4-based metres), the metron, rather than the colon, is the lowest level of the constituent hierarchy where most constraints have a strong effect. This is analogous to how measures in $\frac{6}{8}$ and $\frac{4}{4}$ time signatures correspond to different levels in the metrical grid if we take eighth notes as the lowest level of the grid in both.[14] Thus, I start by ranking 6-mora metra in terms of well formedness in Table 6, applying the same constraints and the same weights as before but shifting their scope of action one level down in the hierarchy. The letter *m* indicates that the constraint's

[14] In fact, 4-based cola correspond to metra in other metre classes in many ways. For instance, verse-final pauses are normally long enough to make verse length a multiple of metron length. In 4-based metres, however, they are long enough to make verse length a multiple of colon length (e.g. see recording 36). The preferred tapping frequencies of the subjects in the experiment conducted by Mirzaee et al. (2019) exhibit a similar correspondence between cola in 4-based metres and metra in other metres.

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Metron	H-FINAL *m* w=4	ALGSYL *f* w=3	H-INITIAL *m* w=2	Sum
1. HLLH				0
2. LHLH			*	2
3. HHH		*		3
4. HLHL	*			4
5. LLHH		*	*	5
6. LHHL	*		*	6
7. HHLL	*	*		7
8. LLHLL	*	*	*	9

Table 6
6-based metra ranked in order of well formedness.

violations are examined at the metron level, and *f* indicates the foot level. Violations of *HHH are not considered here because unlike the 4-based case, the rows in this table do not correspond to individual metre families and unlike the other constraints, *HHH is sensitive to how metra are arranged in a metre. I examine the effect of this constraint below when discussing metre families.

In practice, the last three metra (i.e. those with violations scores greater than 5) never show up in our list of common metres. Of the remaining five, HHH is also absent from these metres in spite of being well formed for reasons discussed later in this section.

As the next step, we may discuss the circumstances under which two metra can cooccur in a colon. Persian metres have a general tendency towards repetition. This tendency, which is well known in poetry and exists in musical rhythm too (Lerdahl & Jackendoff 1983), is inviolable at the colon level (as mentioned earlier) and relatively powerful at the metron level as well. It is therefore natural that concatenating two instances of the same metron generally results in a well-formed colon.

Given this tendency towards full resemblance between co-occurring metra, it is natural to expect that even in cases where nonidentical metra co-occur, they must be to some extent similar. We may use 'edit distance' (how many atomic edit operations are needed to get from one sequence to the other) as a measure of similarity. One of the atomic operations that can get us from any of the four well-formed 6-mora metra to another is swapping adjacent L and H syllables, which amounts to moving an event to an adjacent silent pulse. For instance, LLHH ('|||.|.') is only one swapping operation away from LHLH ('||.||.'). If we take one swapping operation as the minimum edit distance allowed between co-occurring metra, the first three pairs in Example (13) would be the only well-formed 6-based pairs.[15] The other edit operation that may count as minimal is replacing a silent pulse by an evented pause (or vice versa). This would get us the last two rows in Example (13).

[15] Note that it is not being suggested that in a colon such as 'LHLH - LLHH' an operation is actually performed to derive any of the metra from the other. We are only using edit operations as a measure of similarity. This can be viewed as a form of output–output correspondence.

(13) (a) HLLH, HLHL
(b) HLLH, LHLH
(c) LLHH, LHLH
(d) HHH, HLLH
(e) HHH, LLHH

Having identified well-formed 6-based metron pairs, we may now compare different potentially well-formed 6-based cola, as shown in Example (7). Violations are calculated as we did for 4-based cola, only moving the relevant level of the hierarchy from cola to metra. A violation occurring in both metra is counted twice. To save room, wherever the violation scores happen to be the same irrespective of the order of the metra, only one of the two possible cola is presented, with the ⇄ symbol next to it. Violation counts above two are written in digits. It must be noted that this table only gives a rough view of well formedness in 6-based cola. There are most likely other, less important, factors affecting well formedness of cola that are being ignored here (e.g. the effect of H-final and H-initial constraints at the colon level).

As Table 7 shows, all cola containing HHH metra are relatively ill formed chiefly because of inducing too many *HHH violations. This explains their absence from our list of common metres. However, there is an additional reason for their unpopularity. In general, using H in place of LL is allowed in Persian poetry (Shamisa 2004). This means that colon 7 in Table 7, for instance, does show up in many poems, but only as a noncanonical form of 'HLLH-HLLH'. This interchangeability causes such a colon to be rarely used as part of the 'canonical form' of a metre; any poem starting with lines based on this colon is likely to drift towards the more well-formed 'HLLH-HLLH' and allow the poem to be counted as based on 'HLLH-HLLH'.

Colon	H-FINAL *m* w=4	ALGSYL *f* w=3	H-INITIAL *m* w=2	*HHH w=1	Sum
1. HLLH - HLLH					0
2. HLLH - LHLH⇄			*		2
3. LHLH - LHLH			**		4
4. HLLH - HLHL⇄	*				4
5. LHLH - LLHH⇄		*	**		7
6. HLHL - HLHL	**				8
7. HLLH - HHH⇄		*		5	8
8. LLHH - LLHH		**	**		10
9. HHH-LLHH		**	*	4	12
10. HHH - HHH		**		10	16
11. LLHH - HHH		**	*	8	16

Table 7
6-based cola ranked in order of well formedness.

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	Family
1.	HLLH - HLLH - HLLH - …
2.	LLH - HLLH - HLLH - …
3.	LH - HLLH - HLLH - …
4.	H - HLLH - HLLH - …
5.	LHLH - LHLH - LHLH - …
6.	HLHL - HLHL - HLHL - …

Table 8
Simple 6-based metres.

Having identified well-formed 6-based cola, we may now begin examining how they produce the common 6-based Persian metre families (as listed in Table 3). First, let us consider metres that contain only a single type of metron. I call such metres 'simple' and metres that contain more than one type of metron 'complex'.

Interestingly, the sets of syllable sequences for some such simple metres overlap. For instance, the anacrustic metre family 'H - LHLH - …' has the same syllable sequence as 'HLHL - HLHL - …'. Therefore, for this syllable sequence, both scansions seem plausible. However, upon hearing this syllable sequence, listeners strongly prefer the latter metrical analysis. This can be explained by a general preference for nonanacrustic forms. GTTM supports this, viewing anacrusis as a manifestation of group structure being out of phase with metrical structure and punishing it through a Metrical Preference Rule (p. 76). In such cases, we say that the less well-formed analysis for the syllable sequence 'HLHLHLH…' was HIJACKED by the more well-formed one. The relationship between HLLH and LLHH is even more interesting; in this case, HLLH is so well formed that anything based on repetitions of LLHH is always hijacked by a reading based on HLLH. Even the nonanacrustic form 'LLHH-LLHH-…' is hijacked by 'LLH-HLLH-…'.

A list of all simple 6-based metre families is shown in Table 8. Hijacked forms (i.e. all forms based on repetitions of LLHH and all anacrustic forms based on repetition of LHLH and HLHL) are omitted. What remains is exactly the set of simple 6-based metre families we set out to account for, as seen in Table 3.

Even though frequencies are generally ignored in this paper, a word about frequency differences among the metre families based on HLLH (Table 8) seems pertinent here. Metres belonging to row 3 are particularly rare; their overall frequency is less than 0.1%, while the other three have frequencies 1.2%, 7.3% and 11.2%, as we saw earlier in Table 1. This reflects a general tendency that is seen in other parts of the Persian metre inventory too. I tentatively present this tendency as a constraint here, even though, unfortunately, no motivation outside of the data in Persian metrics can be seen for it at this point.[16]

[16] The fact that the constraint's formulation refers to omitted parts of the structure is a potential source of concern. However, note that the 'omitted' parts are not exactly nonexistent; they can be viewed as moras realised through pauses rather than linguistic content.

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Omission: The moraic length of the omitted portion of an anacrustic constituent must be even.

This constraint works against using LH as anacrusis here as it omits three moras from the full metron (HLLH), explaining the low frequency of row 3. In fact, simple metres based on the highest ranking 6-based metron (HLLH) are the only metres that can afford having LH as anacrusis (although as a rare form). In other cases, Omission is never violated (as seen in the following sections).

4.4. *Complex 6-based metres*

The well-formed 6-based cola of Table 7 produce the complex metre families shown in Table 9. Potential metre families that violate Omission are not listed. This yields the set of complex 6-based metre families that we wished to account for (see Table 3). Similar to the case of simple metres, some of these metre families share their syllable sequences. In front of each row's id, the id of the row with which it shares its syllable sequence is written in square brackets. In all cases, both readings are available for the syllable sequence (although in most cases one is dominant). For instance, the participants in the experiment conducted by Mirzaee et al. (2019) prefer 14 over 8, but in recording 19 in the database, the taps are based on the analysis of row 8.[17]

		Family
1.		HLLH - LHLH - HLLH - LHLH - ..
2.		LLH - LHLH - HLLH - LHLH - …
3.		H - LHLH - HLLH - LHLH - …
4.		LHLH - HLLH - LHLH - …
5.		H - HLLH - LHLH - …
6.	[12]	HLLH - HLHL - HLLH - HLHL - …
7.	[13]	LLH - HLHL - HLLH - HLHL - …
8.	[14]	H - HLHL - HLLH - HLHL - …
9.	[15]	HLHL - HLLH - HLHL - …
10.	[11]	LHL - HLLH - HLHL - …
11.	[10]	LHLH - LLHH - LHLH - LLHH - …
12.	[6]	H - LLHH - LHLH - LLHH - …
13.	[7]	LLHH - LHLH - LLHH - …
14.	[8]	HH - LHLH - LLHH - …
15.	[9]	H - LHLH - LLHH - …

Table 9
Complex 6-based metre families.

[17] This metre family is exceptional in that quite surprisingly, it has a relatively popular 4-based analysis too (as illustrated in recording 20), even though it does not have a repeating cycle that is a multiple of four.

4.5. *Odd metres*

A new constraint is required in addition to the ones introduced previously to account for well-formed odd metra:

LONG-FIRST: In odd metra, the extra mora must be on the first foot.

Recall that one of the feet in an odd metron is longer than the other one. This constraint favours metra in which the longer foot comes first. If we view odd metrical structures as altered versions of even structures, the foot with the augmented mora can be seen as more complex. This is reminiscent of the 'closure' principle, which, under Hanson and Kiparsky's (1996) account, states that metrical structures can be more 'strict' in a noninitial position or foot and more 'relaxed' in an initial position or foot. If we allow ourselves to extend the concept to a unit as small as the metron, the augmented mora can be seen as an extra source of complexity which is preferred to occur in its initial foot.

The ranking for 7-mora metra is shown in Table 10. I propose the weight 2 for the 'long-first' constraint. Foot boundaries are shown with dots. In each row, the foot boundary is placed in the position that would be least costly in terms of constraint violation. Since there are no common complex odd metres, the rows of this table correspond to entire metre families. Therefore, we may include *HHH violation calculations in this table as we did in the case of 4-based metres.

Only the first two metra have a visible presence among common Persian metres. A list of 7-based metre families based on the most well-formed 7-based metron (HHLH) is shown in Table 11. As always, the family violating OMISSION ('H-HHLH-…') is not included.

Of the potential metre families based on the second 7-based metron (LLHLH), only the nonanacrustic ones are common in Persian poetry (see Table 1). The third 7-based metron (HLHH) is not entirely ill formed either. The nonanacrustic family based on this metron shares its syllable sequence with that of row 2 in Example (11).

	H-FNL *m* w=4	ALG-SYL *f* w=3	H-INTL *m* w=2	LNG-FST *m* w=2	*HHH w=1	Sum
1. HH.LH					*	1
2. LLH.LH			*			2
3. HL.HH				*	*	3
4. LH.LLH			*	*		4
5. HLL.HL	*					4
6. LH.HH			*	*	*	5
7. HH.HL	*				**	6
8. HL.HLL	*			*		6
9. LLH.HL	*		*			6
10. LH.HLL	*		*	*		8

Table 10
7-based metra ranked in order of well formedness.

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	Family
1.	HHLH - HHLH - HHLH - …
2.	HLH - HHLH - HHLH - …
3.	LH - HHLH - HHLH - …

Table 11
Metre families based on HHLH.

This allows acceptable alternative readings for metres with this syllable sequence. Recordings 2 and 3 in the online database show readings of this metre family based on anacrustic HHLH, and recording 4 shows a reading based on repetitions of HLHH.

The case of 5-based metres is quite similar to that of 7-based metres. The ranking table for 5-based metra is presented in Table 12.

The metre families based on the most well-formed 5-based metron (HLH) are presented in Table 13. The family 'H-HLH-…' is not included since it violates Omission.

Here again, similar to the 7-based case, a nonanacrustic repetition of the marginally well-formed metron LHH (the second most well-formed 5-based metron) is available as a secondary reading for row 2, but the reading based on HLH prevails.

This concludes our coverage of the Persian metre inventory. To cover these metre families, I used two constraints on the syllable sequence (*LLL and *HHH), four constraints on constituent structure (H-final, H-initial, Long-First and Align-Syllable) and three tendencies in the arrangement of constituents next to each other

	H-fnl *m* w=4	Alg-Syl *f* w=3	H-intl *m* w=2	Lng-fst *m* w=2	*HHH w=1	Sum
1. HL.H						0
2. LH.H			*			2
3. H.HL	*			*		5
4. LH.LL	*		*			6
5. LL.HL	*		*	*		7

Table 12
5-based metra ranked in order of well-formedness.

	Family
1.	HLH - HLH - HLH - …
2.	LH - HLH - HLH - …

Table 13
Metre families based on HLH.

(the Omission constraint, a tendency to avoid dissimilar constituents in a line and a preference for nonanacrustic forms).

5. Previous approaches

I now take a step back to compare the present approach against Hayes's (1979) analysis, as it is the only comprehensive generative account of the system. A brief overview of his account is presented below.

In Hayes's analysis, there are three basic forms for 6-mora constituents: LLHH, HLLH and HHLL (all ultimately derived from HHH through the replacement of an H with LL). All three of these forms are composed of three consecutive 2-mora units (which Hayes calls beats) and correspond to 3-beat measures. Certain 6-based metres are accounted for simply as repetitions of one of these 6-mora forms. Note that all such metres are analysed as based on HLLH (with or without anacrusis) under the present theory.

There are many 6-based metres that cannot be analysed in this way. For these metres, Hayes assumes a base 12-mora unit composed of two repetitions of one of the three main forms (LLHH, HLLH and HHLL) and then derives the metre through swapping adjacent syllables in these 12-mora units. Examples of such derivations are shown in Example (14). The swapped syllables are underlined.

(14) (a) L$\underline{\text{LH}}$H - LLHH → L$\underline{\text{HL}}$H - LLHH
(b) LLHH - L$\underline{\text{LH}}$H → LLHH - L$\underline{\text{HL}}$H
(c) LLH$\underline{\text{H}}$ - $\underline{\text{L}}$LHH → LLH$\underline{\text{LH}}$LHH
(d) HHL$\underline{\text{L}}$ - $\underline{\text{H}}$HLL → HHL$\underline{\text{LH}}$HLL

Hayes also derives the 7-based metres from HHH, this time by inserting an L before one of the H's. This produces three 7-mora forms: LHHH, HLHH and HHLH. Each 7-based metre is simply composed of repetitions of one of these. The 5-based metres are accounted for in a similar manner; HLH and LHH are derived by inserting an L before the H syllables in another base form: HH. Each 5-based metre is simply a repetition of one of these sequences.

We may now compare Hayes's analysis with the one presented here in certain key points. The most obvious argument against Hayes's account in light of the present data is that it cannot account for the tapping patterns of the metres. This by itself is an important drawback, especially for a theory such as Hayes's that assumes a structure based on musical rhythm for the metres. However, there are other important theoretical and empirical issues to be noted.

First, in the old 'left-to-right' fragmentation method, the relationships between different metre families are missed. The anacrustic and nonanacrustic metre families based on HLLH, for instance, are related as manifested in certain poetic genres (see Section 3). Such empirical observations have no explanation if, for instance, one metre family is analysed as based on HHLL and the other as based on LLHH.

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Second, ill-formed constituent boundaries occur quite a few times in left-to-right fragmentations. Examples (14c) and (14d) show two quite well-sounding metre families that have H syllables straddling major constituent boundaries under these accounts. To overcome this problem, both Hayes (1979) and Deo & Kiparsky (2011) argue that these metres are derived through swapping from forms that do not have boundary-straddling H syllables (as shown in Example (14)).

Third, Hayes's theory fails to account for quite a few well-formed metres. For instance, the metre family analysed here as 'LH-HLLH-HLLH-…' is not predicted directly by Hayes's analysis. This family is found perfectly well formed by participants of the tradition and appears tens of times in both Elwell-Sutton's and Parhizi's corpora (example poems are presented in recordings 9, 33 and 38). Under the left-to-right fragmentation method Hayes has adopted, a direct analysis of this metre family would require accepting LHHL as a metron, but this would go against his entire logic for deriving the 6-based metra. To overcome this problem, he suggests there is a silence at the beginning of metres belonging to this metre family. No further motivation is presented for the existence of such silence, nor is any explanation given as to why this syllable sequence in particular allows a preceding silence. His analysis also misses metres based on the 7-mora constituent LLHLH. This is in fact the most common metre family (16th in terms of frequency in Parhizi's corpus) that Hayes does not even mention. This dismissal arises from the fact that Elwell-Sutton's list omits it, considering it – for reasons he does not specify – to be a pure imitation of Arabic metres. Incorporating this metre family into Hayes's theory is not easy. Simply arguing that HHLH can change to LLHLH leaves open the question of why LHHH and HLHH (both of which he considers to be valid 7-mora constituents) do not undergo similar processes to produce LHLLH and HLHLL as equally well-formed metra. Under the present theory, the same constraint weights that account for metra of other sizes correctly predict that LLHLH is the second most well-formed 7-based metron.

The class of 4-based metres are also entirely ignored in Hayes's work. Again, incorporating them into his work is not easy. If we follow Hayes's approach for 6-based metres and take LLH and HLL as the base 4-mora constituents, there are many valid cola that cannot be achieved through a single syncopation, for example, LHL-HH, HLL-HH, HLHLH and LLH-HH. Opening the door in Hayes's theory to additional operations immediately results in overgeneration.

6. Conclusion

The account of Persian metres presented here draws on data from the tapping patterns participants associate with metres (established through an online database of recordings, the author and two consultant's judgments and reports from previous scholars). The following points highlight the main characteristics of this account.

1. Syllables' weights do not carry direct information about the metrical positions they may be matched with. In some cases, a single syllable sequence may be assigned entirely different accent hierarchies.

2. A hierarchy of metrical accents (which manifest themselves through tapping patterns) determines the constituency tree of a metrical form.
3. Many Persian metres begin with incomplete constituents (anacruses).
4. Persian metres are either simple or compound, and either normal or with an augmented mora in each metron. These two distinctions make up the four classes of Persian metres.
5. The metrical system is accounted for as a weight-assignment regime to universal rhythmic constraints. Anything that ranks high enough, whether attested or not, is judged as well formed and is part of the Persian metre inventory.

Two directions for future research present themselves. First, a survey of poetic licenses in the Persian metrical system and how the present theory can account for them needs to be performed. More importantly, the utility of this approach in accounting for related quantitative metrical systems such as those of Arabic and Classical Greek remains to be demonstrated.

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