The alignment of L + H* pitch accents in Persian intonation

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This paper investigates how the tonal targets of rises in Persian are phonetically realized in relation to the segmental string. Three types of cliticized Persian Accentual Phrases (APs) are instrumentally compared with one another: high-boundary-toned pre-nuclear APs, low-boundary-toned nuclear APs, and low-boundary-toned contrastive focus APs. The results show that the valley is always aligned with the consonant preceding the stressed vowel, but the alignment of the peak is with the consonant following the stressed vowel if the AP boundary tone is low, and with the following vowel if it is high. The duration of the focus AP is greater than that of the other two. The pitch excursion of the focus AP is significantly greater than that of the nuclear type. This difference is caused by different peak heights. While pre-nuclear and nuclear APs can be phonologically represented by L + H*, focus APs, which are pragmatically different, warrant a distinct pitch accent, namely L + ˆH*. The systematic alignment of the L and the H, and the variability of the time and slope of the rise support the view that pitch targets rather than pitch movements are the fundamentals of Persian intonation.

1 Introduction

This paper examines some of the phonetic properties of Persian intonation. The study attempts to determine whether the tonal targets of the Persian Accentual Phrase (AP) are regularly timed against segments and how the existence of contrastive focus affects timing. This is done by comparing the alignment patterns of different types of Persian APs. Thus, this paper seeks to reach two main objectives. The first goal is to shed some light on the phonetic aspects of an intonationally under-documented language, and to verify whether the autosegmental-metrical (AM) theory of intonation (e.g. Pierrehumbert 1980, Ladd 1996) is the appropriate framework for studying this language. The second purpose is to take a step in enriching the typological studies of intonation by adding another language to the ones already investigated, and to pave the way to a more refined theory of intonation by comparing and contrasting a greater number of languages.

The research on alignment patterns started with Bruce's (1977) work on Stockholm Swedish word accents, which differentiated between two accent types on the basis of two different alignment patterns of the F0 peak. Bruce observed that accented syllables are always characterized by a fall in pitch from a peak to a valley and found that the phonetic realization of this fall is different for the two accent types: in Accent I (or acute accent), the fall is aligned before the accented syllable, and in Accent II (or grave accent), it is

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aligned later, namely at the beginning of the accented vowel. The AM theory has, in recent years, motivated much research on the alignment patterns of tonal targets with respect to segmental landmarks, e.g. Prieto (2002) on Catalan; Ladd, Mennen & Schepman (2000) and Schepman, Lickley & Ladd (2006) on Dutch; Arvaniti & Gårding (2007) on American English; Grabe (1998), Ladd et al. (1999), and Ladd & Schepman (2003) on British English; Welby (2002, 2006) on French; Grabe (1998) and Mücke et al. (2006) on German; Atterer & Ladd (2004) on Southern and Northern German; Arvaniti, Ladd & Mennen (1998, 2000, 2006) on Greek; D'Imperio (2001) on Neapolitan Italian; Gili Fivela (2002) on Pisa Italian; Ishihara (2003) on Japanese; Xu (1998, 1999) on Beijing Mandarin; Frota (2002) on European Portuguese; Elordieta & Calleja (2005) on two varieties of Basque Spanish; Willis (2003) on Dominican Spanish; Face (2001) on Peninsular Spanish; Igarashi (2004) on Russian; Bruce (2003) on West Swedish. The present paper is a first attempt on the study of alignment in Persian.

Intonational research of this type has led to discussions in at least two different areas. One is the question of the fundamentals of an intonational analysis. Some researchers believe that pitch movements are the fundamentals of intonation, among which those of the British school (e.g. Crystal 1969) and the IPO school ('t Hart, Collier & Cohen 1990) can be named. Such authors maintain that the intonation contours of a language are best described in terms of a set of discrete pitch movements. The AM researchers of intonation, on the other hand, believe that the primitives of intonation are pitch targets such as high and low, and the F0 movements are defined in terms of their beginning and ending points. The present paper will contribute to the above discussion.

The other issue concerns the alignment differences observed among languages. A summary of some of the attested languages and dialects includes the following. The alignment of L in pre-nuclear rises is at or slightly before the onset of the stressed syllable in Greek (Arvaniti et al. 1998), British English (Ladd et al. 1999), Dutch (Ladd et al. 2000), Lekeitio Spanish and Vitoria Spanish (Elordieta & Calleja 2005). In Northern German, it is aligned later, i.e. well within the initial consonant of the stressed syllable, and in Southern German, it can be aligned still later, i.e. as far as early in the stressed vowel (Atterer & Ladd 2004).

The alignment of H in pre-nuclear rises is just after the onset of the post-stress vowel in Greek (Arvaniti et al. 1998) and Northern and Southern German (Atterer & Ladd 2004). In British English, it is aligned late in the post-stress consonant (Ladd et al. 1999). In Dutch, it can occur near the end of the stressed vowel – if the vowel is phonologically long – and midway in the following consonant – if the vowel is phonologically short (Ladd et al. 2000). In Lekeitio Spanish and Vitoria Spanish, it is aligned before and after the offset of the stressed syllable, respectively (Elordieta & Calleja 2005).

In nuclear rises, the alignment of tones, specially that of H, is generally earlier than in pre-nuclear ones: two-thirds of the way through the stressed vowel in Greek (Arvaniti et al. 2006), in the second half of the stressed vowel in Dutch (Schepman et al. 2006), during the post-stress consonant in German (Mücke et al. 2006), and with the stressed syllable in Lekeitio Spanish and Vitoria Spanish (Elordieta & Calleja 2005). The alignment of L in nuclear rises is earlier than the pre-nuclear counterpart in Vitoria Spanish (Elordieta & Calleja 2005).

Drawing on an analogy with voice onset time in plosives, Atterer & Ladd (2004) suggest that alignment differences among languages are gradient rather than categorical, in the sense that the underlying tonal association is the same in each case, and the alignment differences can be accounted for by language-specific phonetic implementation rules. The gradient vs. categorical differences in alignment patterns will be investigated in the present paper in relation to the Persian data. It will be seen whether the differences among the Persian AP types warrant separate phonological representations, or can be handled by the phonetics of Persian intonation.

The organization of the paper is as follows. The next sub-section provides an overview of Persian prosodic structure. Section 2 contains the details of the experiment, and section 3 concludes the paper. The stimuli used are provided in the appendix.

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1.1 An overview of Persian prosodic structure

Persian is an Iranian language belonging to the Indo-Iranian sub-branch of the eastern branch of the Indo-European language family and is classified as an SOV language (Dabir-Moghaddam 1982, Karimi 2005). Jun (2005) classifies Persian with English, German, Dutch, Greek, Italian, Spanish, Portuguese, Lebanese Arabic, and Bininj Gun-wok (a Northern Australian language) as 'stress-accent' languages, i.e. languages in which a certain syllable in a word is made more prominent than other syllables by phonetic factors, showing syntagmatic contrast. Nouns (*ʃuné* 'comb'), adjectives (*kutáh* 'short'), and most adverbs (*jæváʃ* 'slowly') have word-final stress, and verbs are stressed on the final syllable of the main constituent (*xæríd-æm* 'I bought'). For more on Persian stress, see e.g. Lazard (1992), Same'i (1996), Mahootian (1997), Vahidian-Kamyar (2001), Kahnemuyipour (2003), and Parmoon (2006). Pitch accents in Persian occur on the lexically stressed syllables (Eslami & Bijankhan 2002, Eslami 2003).

Researchers working in the framework of the AM theory of intonation assume that there are (at least) two levels in the hierarchy of Persian prosody, the Accentual Phrase (AP) and the Intonational Phrase (IP) (Jun et al. 2003, Mahjani 2003, Sadat-Tehrani 2007). The Persian AP has only one configuration: a low followed by a high, characterized by the pitch accent L + H* which is associated with the stressed syllable. This pitch accent may be realized as an allophonic H* in, for instance, initially-stressed words and monosyllabic content words, when no segmental material is available for the realization of L. The Persian AP normally consists of one content word together with its possible clitics. A high (h) or low (l) boundary tone marks the right edge of an AP, the former being used in pre-nuclear APs and the latter in nuclear APs. A nuclear AP is always the last AP in simple mono-clausal sentences of all types, i.e. declaratives, interrogatives, and imperatives (for an account of the location of the nuclear pitch accent in Persian, see Sadat-Tehrani 2008). One or more APs form the next level, the IP, which is marked by a boundary tone L% or H% at the right edge. The number of APs in an IP is affected by factors such as speech rate; for instance, in fast speech, this number may be fewer compared to that in normal rate. The elements following the nuclear pitch accent are deaccented up to the IP end. Example (1) and figure 1 illustrate the prosodic structure of Persian. The nuclear AP is underlined and the stressed syllable of each AP is indicated by an acute accent mark. In the figure, the stressed syllable is demarcated by vertical lines, solid line for the onset and dotted line for the offset.[1]

(1)

miná	milán-æm	mí-mun-ɛ	tʃænd	ruz.
Mina	Milan-too	DUR-stay.PRS-3SG	a few	day

'Mina stays a few days in Milan too.'

The above utterance consists of three APs, the subject (*mina*), the adverb plus its clitic (*milan-æm*), and the verb (*mi-mun-ɛ*). The first two carry the pitch accent L + H* and the third H*. The pre-nuclear APs have a high boundary tone and the nuclear one (the verb) a low boundary tone. The phrase *tʃænd ruz* 'a few days' is deaccented, and the utterance ends low with an L% IP boundary tone which marks it as a declarative.

When an IP contains only one content word, that word is the sole AP and also the nuclear one, as exemplified in (2).

(2)

IP
AP
mí-mun-ɛ .
DUR-stay.PRS-3SG

'[S/he] stays.'

[1] The abbreviations used in this paper are: DEF = definite marker; DUR = durative; IND = indefinite marker; NEG = negation; PL = plural; PRS = present; PST = past; PTC = particle; PTCP = participle; SG = singular; SPEC = specificity marker; '+' separates the two parts of a compound verb.

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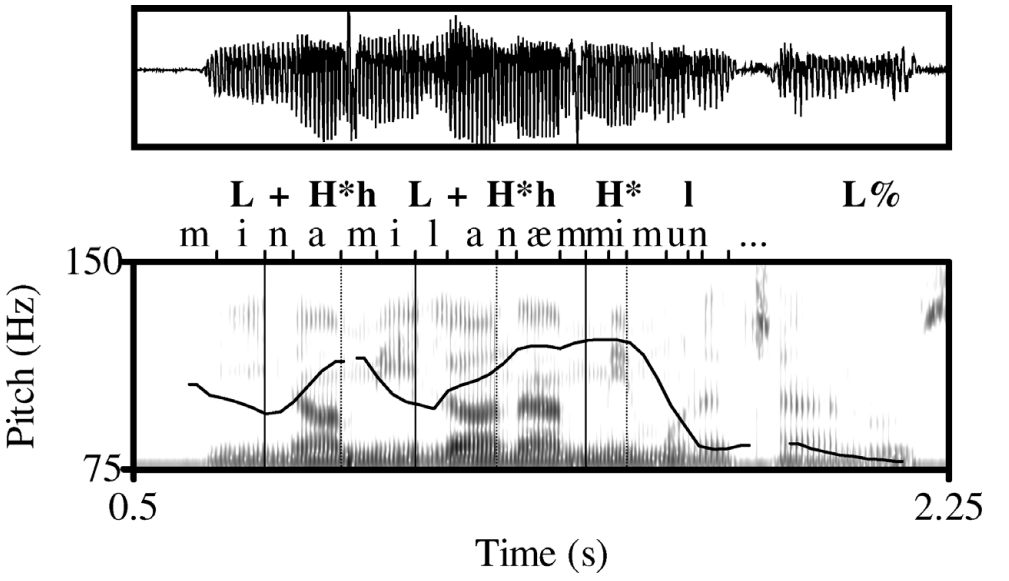

Figure 1 The utterance *miná milán-æm mí-mun-ɛ tʃænd ruz* 'Mina stays a few days in Milan too'. The voice analysis software used is Praat (Boersma & Weenink 2007).

Word order changes do not alter the basic intonational structure. For instance, consider the utterance in (3) and its tonal pattern.

(3) L + H*h L + H*h L + H*l L%
dirúz mamán-ɛt umǽd.
yesterday mom-your come.PST.3SG
'Yesterday your mom came.'

There are three APs in (3), the adverb (*diruz*), the subject (*maman-ɛt*), and the verb (*umæd*). Two other possible word orders of (3) (which result in different pragmatic nuances) are given in (4) together with their tonal patterns.

(4) L + H*l L%
a. umǽd diruz maman-ɛt.
L+H*h L+H*l L%
b. dirúz umǽd maman-ɛt.

The basic intonational structure of the utterances in (4) is the same as that in (3). The verb is the nuclear AP and is characterized by L + H*l. Everything following it is deaccented.

A contrastively-focused element forms its own AP.[2] The AP becomes the nuclear pitch accent of the utterance and has a low boundary tone (l). Everything after a focused element is deaccented. Example (5) and figure 2 illustrate these points (contrastive focus is indicated

[2] Focus is used in different senses in the literature (see e.g. Ladd 1996, Kiss 1998, Zubizarreta 1998, Selkirk 2002, Gussenhoven 2004). Contrastive focus in this paper is taken to mean highlighting one or more elements in contrast to other elements in the discourse, also referred to as 'corrective focus' by Gussenhoven (2007).

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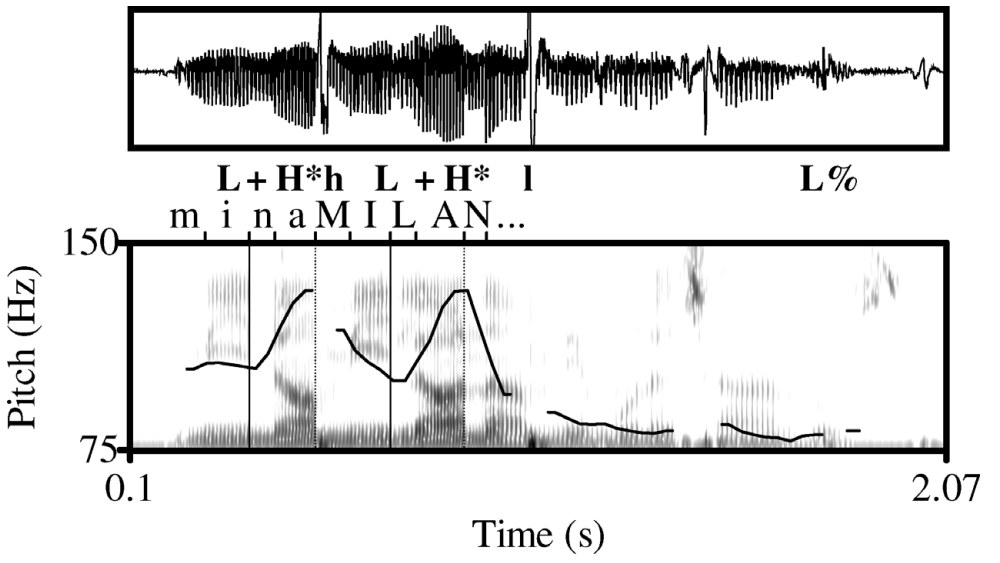

Figure 2 The contrastive focus utterance *miná MILÁN-ÆM mi-mun-ɛ tʃænd ruz* 'Mina stays a few days in MILAN too'.

by capitalization).

(5) miná MILÁN-ÆM mi-mun-ɛ tʃænd ruz.
Mina Milan-too DUR-stay.PRS-3SG a few day
'Mina stays a few days in MILAN too.'

In (5), which might be used to correct someone who has misheard the adverb Milan, the second AP is contrastively-focused and has caused deaccentuation in the materials to follow.[3]

2 Experiment

The experiment was set up to investigate certain phonetic aspects of Persian intonation and to examine the interaction of contrastive focus. To this end, three types of cliticized APs were studied and instrumentally compared. The comparison concerned the alignment of L and H relative to certain segmental landmarks, the normalized difference in the pitch of the valley and the peak, the rise-time, and the duration of the segments and of the whole AP. The APs under investigation all have an L + H pattern with an observable L and H. The choice of cliticized over non-cliticized APs was made due to the fact that the former are longer than the latter and hence all tones have enough space to be concretely realized.

2.1 Method

2.1.1 Design and materials

A total of 120 stimuli were used in this experiment, which comprised 30 utterances read by four native speakers. There were 10 utterances with a pre-nuclear high-boundary-toned test

[3] In line with previous accounts, the pitch accent of the focused element is shown as L + H* in the above example; however, as will be seen later in the paper, contrastively-focused APs are realized differently from the other AP types under investigation and are also pragmatically distinct from them. Based on these facts, it is argued in this paper that focused APs are characterized by a different pitch accent, namely L + ˆH*, the ˆH being the symbol for extra high. We will return to this issue in section 2.3.

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AP, 10 with a nuclear low-boundary-toned test AP, and 10 with a focused low-boundary-toned test AP. In what follows, the above three types are referred to as Pre-nuclear, Nuclear, and Focus types, respectively. A sample set is given in (6). The test AP is italicized. (The list of sentences used in this experiment is provided in the appendix.)[4]

(6) Pre-nuclear: dirúz *namǽ-mun* umǽd.
yesterday letter-our come.PST.3SG
'Yesterday our letter arrived.'

Nuclear: mál-ɛ *namǽ-mun* bud.
property-LINKER letter-our be.PST.3SG
'It was for our letter.'

Focus: mál-ɛ *NAMǼ-MUN* bud.
property-LINKER letter-our be.PST.3SG
'It was for OUR LETTER.'

The waveforms and pitch tracks are given in figure 3 with the test APs specified. As before, the stressed syllable is demarcated by vertical lines.

Utterances were elicited by showing written version to speakers on cue cards in a random order. The speakers were asked to use a normal speech rate, neither fast nor slow. Each utterance was read once by each speaker, giving a total of 120 (10×3×4) utterances.[5] In cases where a speaker misread something or there were disfluencies in a production, the speaker was asked to re-read the utterance. Due to the fact that, in Persian, default nucleus placement follows rather straightforward rules (Sadat-Tehrani 2008), in most instances of Nuclear and Pre-nuclear sentences, showing the cue cards to the speakers and asking them to read with a normal (default) pronunciation sufficed to elicit the intended nuclear pitch accent and boundary tones. Only for one of the sentences (sentence (5) in the appendix, Nuclear), in addition to the cue card, a short context was given to the speakers for them to put the nucleus on the right word, since this sentence can have two different pronunciations and meanings. For the Focus type, a prompter question was always asked to cause the test AP to become contrastively-focused. Thus, every time a contrastive focus utterance came up on a card, the experimenter asked the speaker a question whose answer was the utterance on the card. For example, the question for the focus utterance in (6) was (7) below.

(7) mal-ɛ kɛtab-ɛtun bud?
property-LINKER book-your be.PST.3SG
'Was it for your book?'

The test AP (e.g. *namæ-mun* 'our letter' in (6)) was designed to be always preceded and followed by other syllables in the utterance in order to reduce the unwanted utterance-initial and utterance-final effects. In addition, the test AP was always the second AP of the utterance so that it was equally affected in all utterances by possible downstep effects. The consonants surrounding the stressed vowel in the test word were always the sonorants /l/, /m/, /n/ in order for the F0 track of the test word to be smooth and connected.[6]

[4] Note that vowels have different intrinsic pitches (e.g. Laver 1994, Whalen & Levitt 1995) and different durations. Although vowels have not been controlled for within each AP type, they have in fact been controlled for across AP types since the same segments are used for the test AP in all three AP types (e.g. *namæ-mun* 'our letter') which makes the comparison among AP types reliable.

[5] As an anonymous reviewer points out, each utterance could ideally be recorded several times by each speaker to ensure that the recordings represent the normal behavior of speakers.

[6] Note that sonorants can potentially make it harder to segment for durations. This, however, did not turn out to be a problem for the present experiment.

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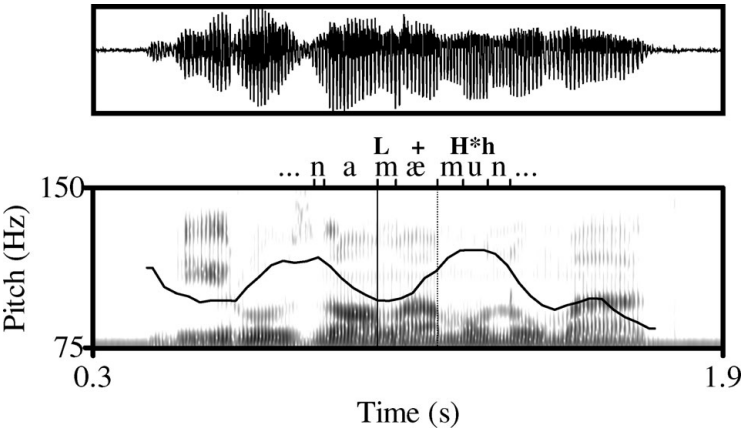

Figure 3a The utterance *dirúz namæ-mun umæd* 'Yesterday our letter arrived' Pre-nuclear AP.

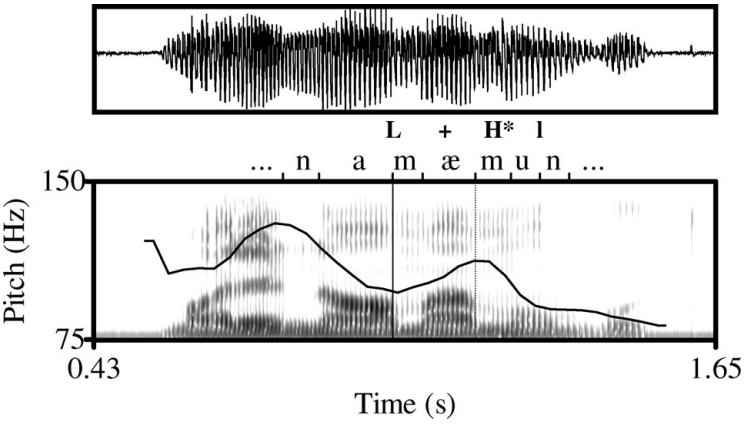

Figure 3b The utterance *mál-ɛ namæ-mun bud* 'It was for our letter' Nuclear AP.

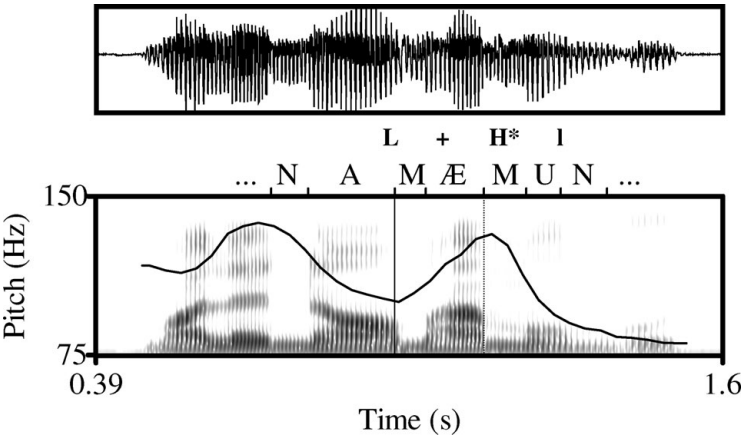

Figure 3c The utterance *mál-ɛ NAMÆ-MUN bud* 'It was for OUR LETTER' Focus AP.

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2.1.2 Speakers

Four speakers, two female (F) and two male (M), took part in this experiment, one of the males being the author (M2). Their ages ranged from 27 to 41 years, all educated native speakers of Tehrani Persian who had lived in Iran all their lives before moving to Canada three to six years before the experiment, and who had grown up as monolingual speakers of Persian. They had been using Persian in some of their daily communications since they left Iran. However, it must be noted that alignment patterns of L1 can change under the influence of L2 (Mennen 2004), and so a study using pure monolinguals may be more representative of native Tehrani Persian alignment patterns.

2.1.3 Procedure

The productions of the speakers were recorded using a Marantz PMD660 professional digital voice recorder and a Shure KSM109 cardioid condenser microphone placed at a fixed distance of about 40 cm from the speaker. The recordings were analyzed in Praat (Boersma & Weenink 2007). About 7.5% of the recordings were discarded since they did not have fully visible valleys and peaks due to the existence of plateaux. Such utterances were re-recorded in a second session. The measurement methodology was basically that of Atterer & Ladd (2004). The following eight landmarks were identified in each test AP.

V1: The beginning of the vowel preceding the stressed vowel (V_{pre})
C1: The beginning of the consonant preceding the stressed vowel (C_{pre})
V2: The beginning of the stressed vowel (V_{str})
C2: The beginning of the consonant following the stressed vowel (C_{post})
V3: The beginning of the vowel of the clitic (V_{cli})
C3: The end of V_{cli}
L: The location of F0 minimum
H: The location of F0 maximum

Note that V1, C1, etc. refer to the BOUNDARIES between segments whereas V_{pre}, C_{pre}, etc. are the segments themselves. The above landmarks help us determine the alignment of the maximum and the minimum of the test AP with regard to the segments. They are also used to calculate the rise-time (H−L). The timepoints for H and L and their respective frequencies were obtained using Praat functions, which automatically move the cursor to the maximum or minimum of the selected part, and the timepoint and pitch can be read off the horizontal and the vertical axes, respectively. Visual inspection of the peak and the valley location supported the Praat judgments in most cases. In a few instances, the H or L was in the form of a short plateau rather than a single point. In such cases, the midpoint of the plateau was taken. The normalized pitch excursion was calculated by dividing the pitch difference of H and L by their mean, as given in (8).

(8) Normalized pitch excursion = (H−L) / [0.5(H+L)]

The other landmarks (i.e. segment boundaries) were determined visually with the help of wide-band spectrograms and waveforms. Figure 4 shows an example of the location of the above landmarks for the Focus sentence in (6), repeated here as (9).

(9) mál-ɛ NAMÆ-MUN bud.
property-LINKER letter-our be.PST.3SG
'It was for OUR LETTER.'

The AP duration was calculated by adding the durations of the relevant segments. These segments were a series of consecutive consonants and vowels for all sentences (i.e. they all consisted of the string $CV_{pre}C_{pre}V_{str}C_{post}V_{cli}$), which ensured the segmental uniformity of the data.

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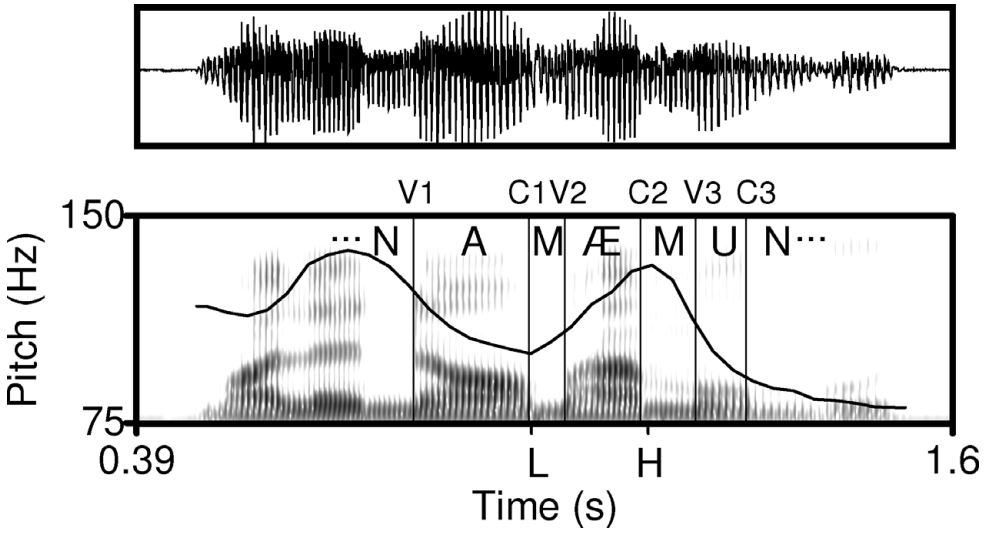

Figure 4 Landmarks for the AP *NAMÆ-MUN* 'OUR LETTER' in a focus production.

2.2 Results

2.2.1 Duration

Figures 5–10 contain the box plots of the different segment durations and the AP durations for individual speakers and for all speakers. Note that the duration of the AP is not necessarily the addition of the durations of the five segments, since in some cases the AP contains another consonant before V_{pre} and/or after V_{cli}.

A repeated-measures ANOVA on the speaker means (with the dependent variable being the AP duration, and the independent factor being the AP type and having three levels) showed that the durations of the three AP types are different ($F(2,6) = 11.65$, $p < .01$). A Tukey-Kramer multiple comparison test revealed that the duration of the Focus AP is significantly greater than that of the Pre-nuclear AP.[7] The duration of the Nuclear AP is between that of the other two types but not significantly different from either.

Of the five segments whose durations were measured, the vowels and not the consonants exhibited significant difference in the three types of AP, as the following repeated-measures ANOVA results show. The ANOVAs are on the speaker means, with the segment duration in each case being the dependent variable and the AP type the independent factor.

V_{pre}: $F(2,6) = 8.70$, $p < .05$
C_{pre}: $F(2,6) = 1.47$, $p = .30$
V_{str}: $F(2,6) = 12.75$, $p < .01$
C_{post}: $F(2,6) = 0.16$, $p = .86$
V_{cli}: $F(2,6) = 31.16$, $p < .001$

Tukey-Kramer multiple comparison tests performed for the vowels showed that the V_{pre} in Focus APs is significantly longer than in Pre-nuclear APs, and that of Nuclear APs is not different from the other two in this regard. The V_{str} of the Focus type is longer than that of

[7] Although the scientific rigour of planned comparisons is more than that of post-hoc comparisons such as Tukey-Kramer tests, the latter were chosen for this paper since it was the first time that such an experiment was done on Persian and there was no previous prediction as to the possible results.

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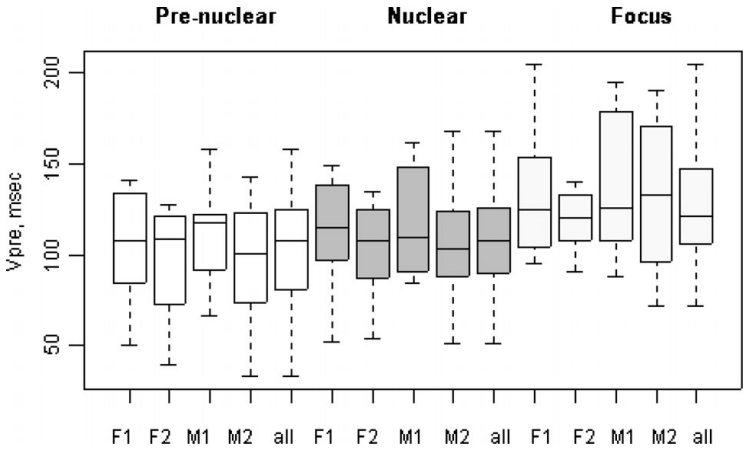

Figure 5 The duration of V_{pre} of the three AP types, for each speaker and for all speakers.

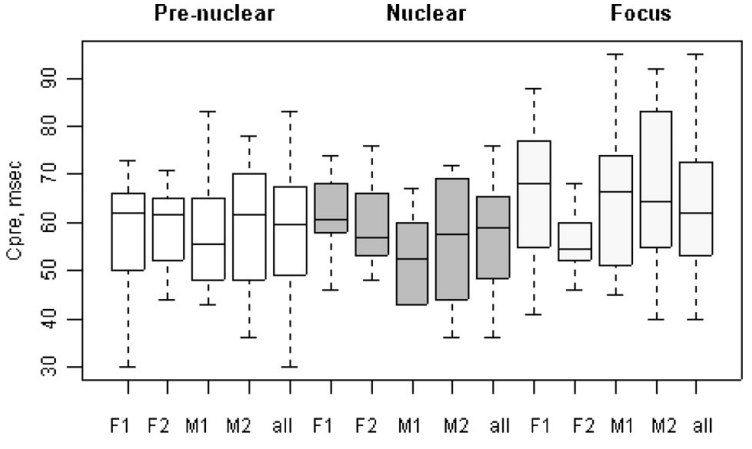

Figure 6 The duration of C_{pre} of the three AP types, for each speaker and for all speakers.

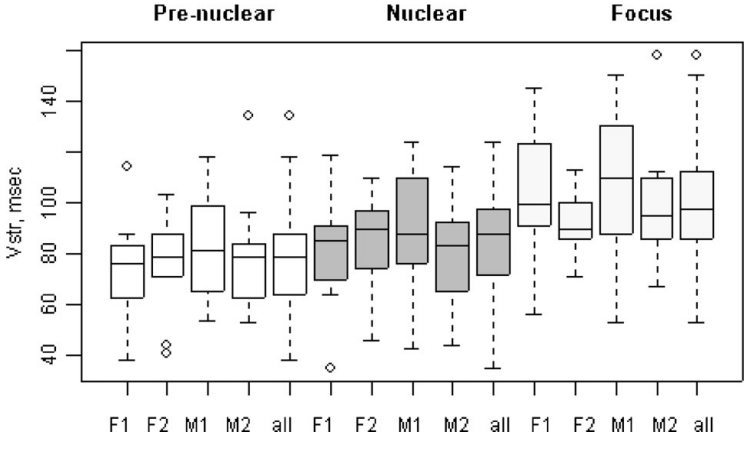

Figure 7 The duration of V_{str} of the three AP types, for each speaker and for all speakers.

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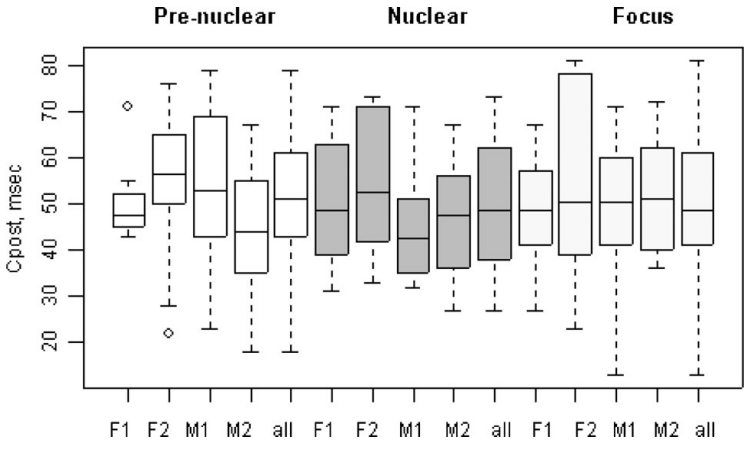

Figure 8 The duration of C_{post} of the three AP types, for each speaker and for all speakers.

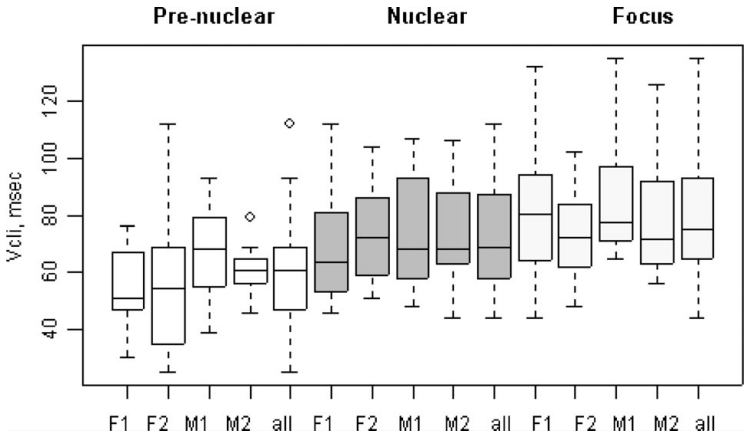

Figure 9 The duration of V_{cli} of the three AP types, for each speaker and for all speakers.

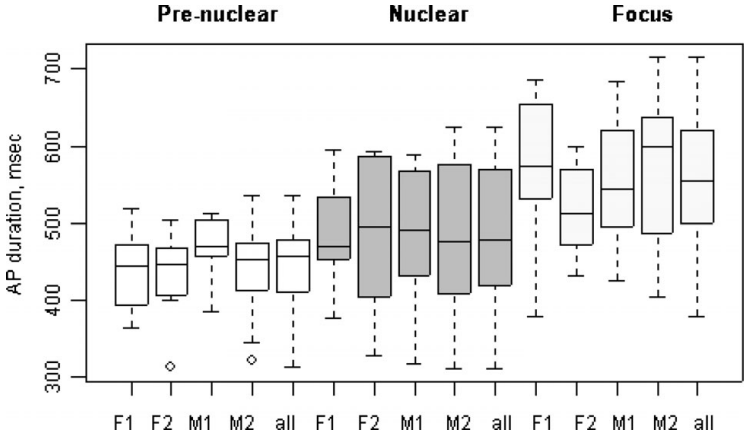

Figure 10 The duration of the three AP types, for each speaker and for all speakers.

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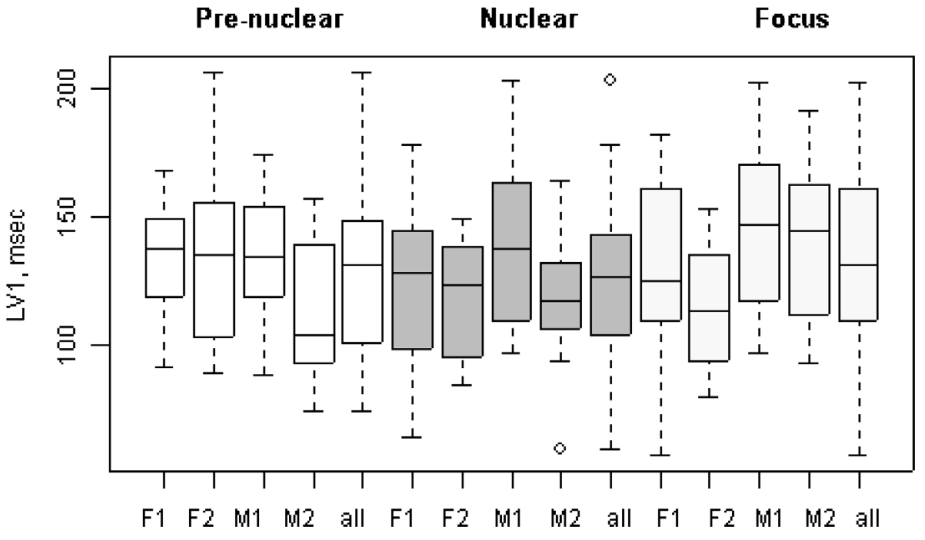

Figure 11 The alignment of L relative to V1 (LV1) for the three AP types, for each speaker and for all speakers.

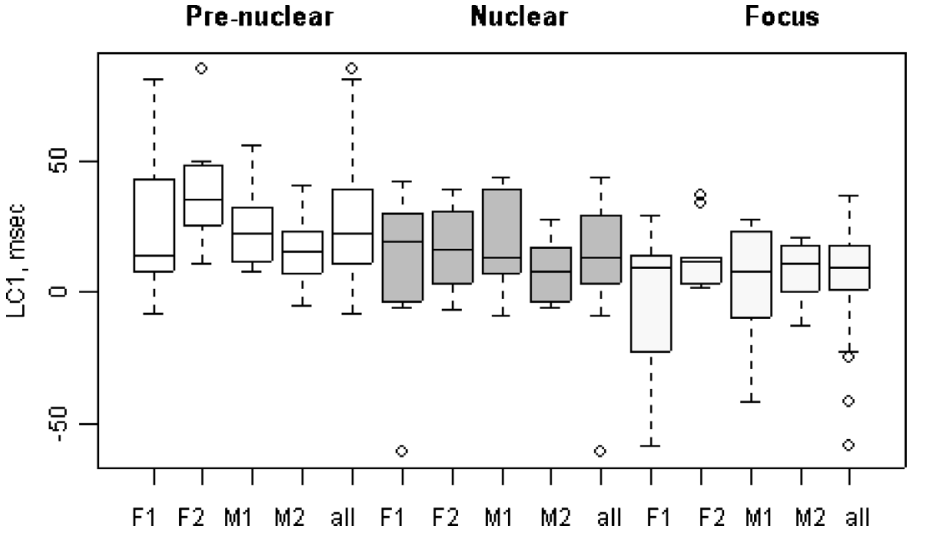

Figure 12 The alignment of L relative to C1 (LC1) for the three AP types, for each speaker and for all speakers.

the other two types, and the V_{cli} of the Pre-nuclear type is shorter than that of the other two types.

2.2.2 Alignment

The box plots of alignment values for each speaker and for all speakers are given in figures 11–14. L and H alignments are given with regard to two reference points each: V1 and C1 for L, and C2 and C3 for H, hence the following variables:

LV1 = The temporal distance between F0 minimum and V1
LC1 = The temporal distance between F0 minimum and C1

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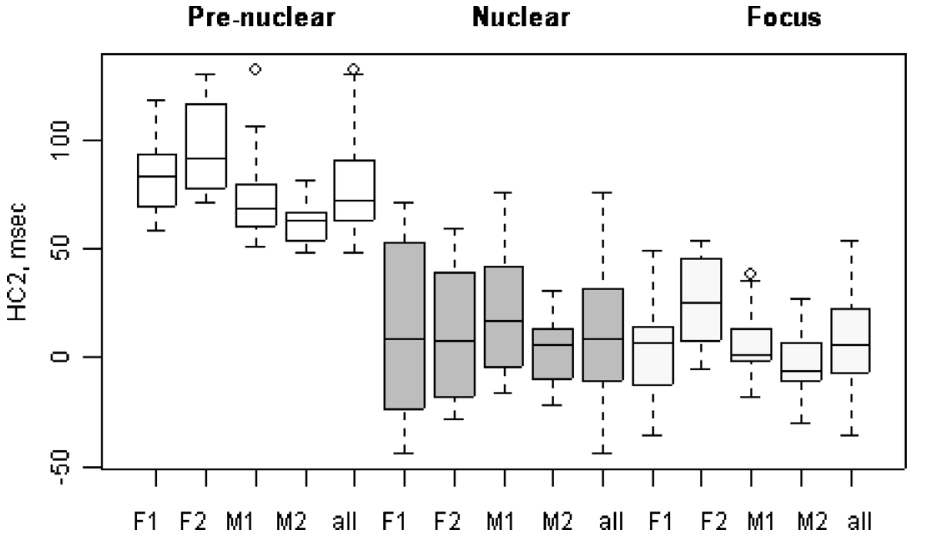

Figure 13 The alignment of H relative to C2 (HC2) for the three AP types, for each speaker and for all speakers.

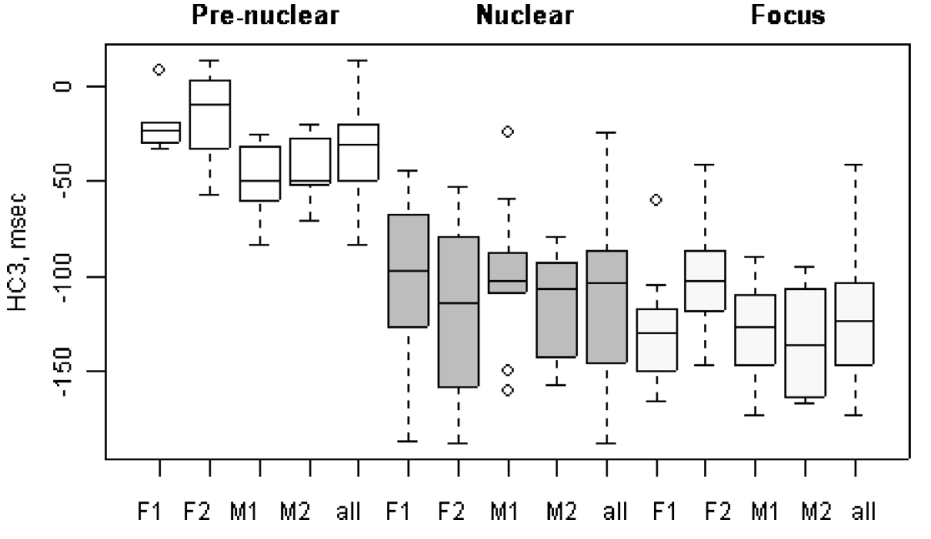

Figure 14 The alignment of H relative to C3 (HC3) for the three AP types, for each speaker and for all speakers.

HC2 = The temporal distance between F0 maximum and C2
HC3 = The temporal distance between F0 maximum and C3

A negative number in the figures denotes that the minimum or maximum has occurred before the reference point. The alignment of L occurs in the consonant preceding the stressed vowel in all three types. A repeated-measures ANOVA on the speaker means with LC1 as the dependent variable determined significant difference among AP types ($F(2,6) = 7.25$, $p < .05$), and Tukey-Kramer multiple comparison tests showed that the difference lies between the Pre-nuclear and the Focus types: in the former, the valley is halfway through the consonant, while in the latter, it is at the consonant onset (an example of which can be observed when

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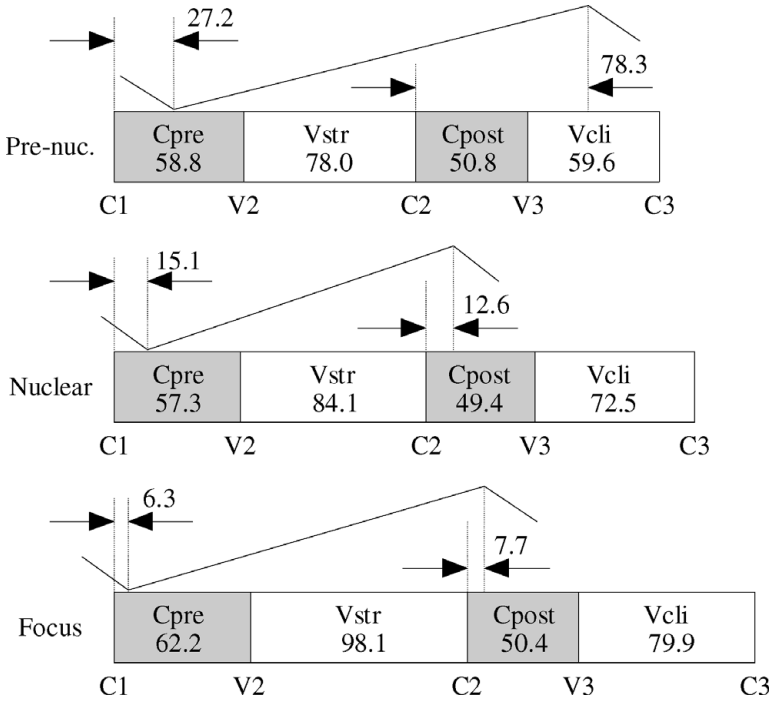

Figure 15 Comparison of alignment in the three AP types (the amounts given are in msec).

comparing figure 3a with figure 3c above). The Nuclear AP has an alignment between the two but not different from either. With regard to the reference point V1 (LV1 being the dependent variable), the alignment difference of L does not reach significance level ($F(2,6) = 0.42$, $p = .68$). This is due to the fact that L is further away from V1 than C1. Schepman et al. (2006) state that the further away a landmark is, the more the probability of unrelated variances becomes, and that alignment is defined more appropriately as the time interval between a tone target and a NEARBY landmark. Therefore, the results from C1 reference point (which is closer to L than V1 is) are more realistic than those of V1, i.e. the alignment of L IS different in Pre-nuclear and Focus APs.

The alignment of H is significantly different relative to both points (HC2: $F(2,6) = 93.11$, $p < .0001$; HC3: $F(2,6) = 61.51$, $p < .0005$), the Pre-nuclear type having later alignment than the other two (Tukey-Kramer tests). H is aligned with the middle of the vowel of the CLITIC in the Pre-nuclear type but in the beginning of the preceding consonant in the other two types. In other words, the AP type with a high boundary tone has a later alignment of H. In the Focus type, speakers F1 and M2 had negative means for LC1 and HC2, respectively. F1's low occurred in the vowel preceding the stressed syllable and M2's high occurred in the stressed syllable. However, these negative averages, which are mainly affected by large negative numbers in only a couple of utterances in each case, do not seem to play a significant role and are not large enough to make the grand mean negative.

Based on the mean alignment values, a schematic representation of alignment locations of L and H in different AP types is provided in figure 15.

2.2.3 Pitch excursion

The box plots of the pitch values of L and H and their normalized pitch excursion (see the formula in (8) above) appear in figures 16–18. The mean Ls of the three AP types are similar

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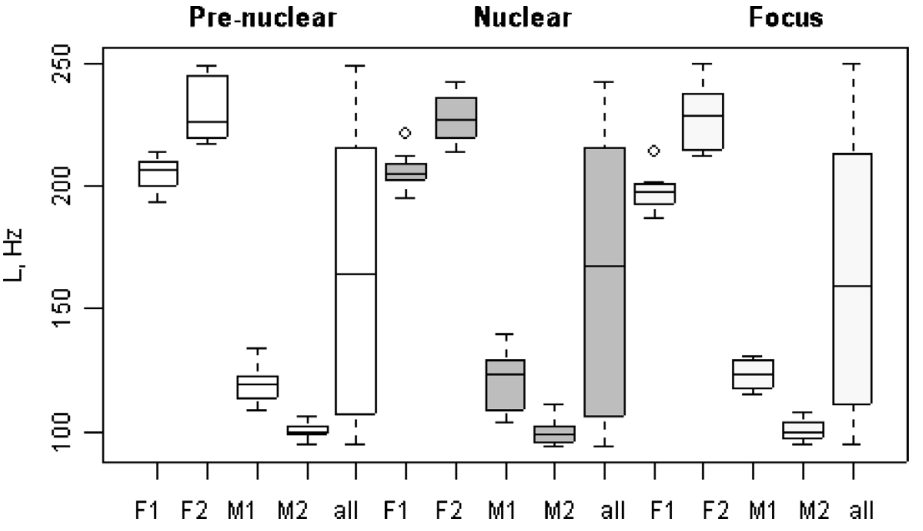

Figure 16 Frequency of L for the three AP types, for each speaker and for all speakers.

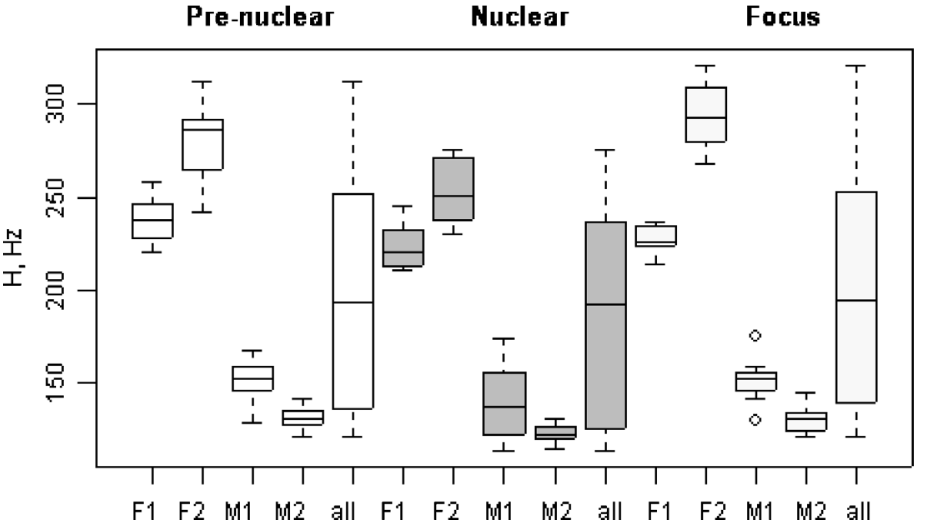

Figure 17 Frequency of H for the three AP types, for each speaker and for all speakers.

and are not significantly different ($F(2,6) = 0.30$, $p = .75$). The Hs show more variation, but the variations do not reach significance level ($F(2,6) = 4.37$, $p = .067$). The normalized excursion is significantly greater in the Focus type than the Nuclear type ($F(2,6) = 14.71$, $p < .01$, and Tukey-Kramer test). The greater excursion of the Focus type is a way to make the contrastively-focused AP more prominent and to render it more salient pragmatically.

2.2.4 Rise-time

The box plots of the rise-time, i.e. the duration between the L and the H in milliseconds, for each speaker and for all speakers combined, are given in figure 19. As figure 19 shows,

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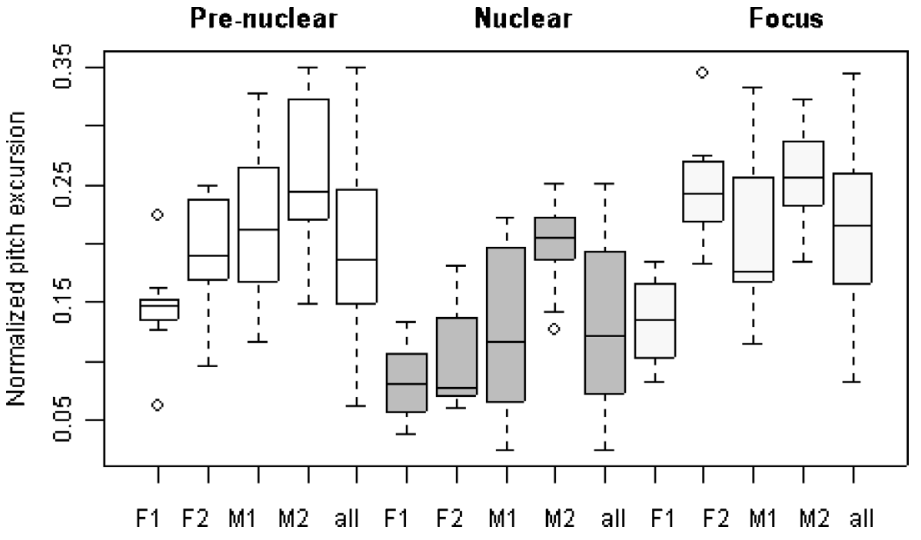

Figure 18 Normalized pitch excursion for the three AP types, for each speaker and for all speakers.

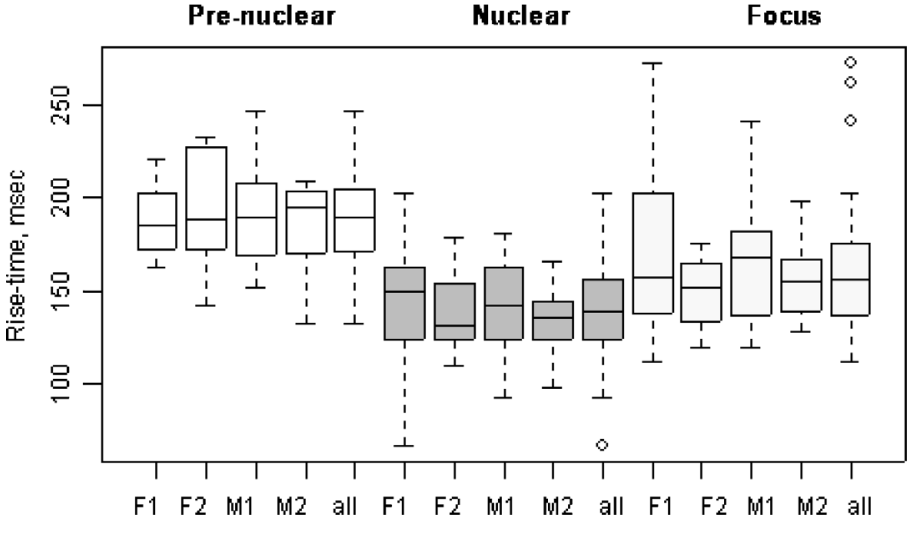

Figure 19 Rise-time of the three AP types, for each speaker and for all speakers.

the rise-time is not of a fixed duration for any of the speakers, e.g. in the Pre-nuclear type, the rise-time ranges from 162.9 to 221.3 msec for speaker F1. This variable rise-time supports the idea that the rise per se is not a primitive of Persian intonation. This issue is further pursued in the Discussion section.

2.3 Discussion

2.3.1 The issue of the fundamentals of Persian intonation

The results reported so far contribute to the question of whether tonal targets or pitch movements are the basics of intonation (see section 1 above). In Persian, the turning points are

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timed in a regular fashion with respect to the segmental string suggesting that pitch targets are the building blocks of Persian intonation, which is in turn supported by the variability of the rise-time in Persian APs. To further investigate this matter, several other measurements and analyses were performed. To check the degree of dependence of the rise-time on the pre-H segments, the correlation of the rise-time with these segments was calculated. For the Pre-nuclear type, this means the correlation of the rise-time with the temporal distance between L and the onset of V_{cli}, and for the Nuclear and Focus type, it means the correlation of the rise-time and the temporal distance between the L and the onset of C_{post}. The assumption was that if target alignment rather than rise-time is primary, then this correlation must be high. The coefficient of determination (R^2) together with the correlation test p-value is given in (10).[8]

(10) Pre-nuclear type: Rise-time and LV3, $R^2 = .477, p < .0001$ high correlation
Nuclear type: Rise-time and LC2, $R^2 = .207, p < .005$ high correlation
Focus type: Rise time and LC2, $R^2 = .676, p < .0001$ high correlation

As can be seen, the pre-H segments are overall good predictors of the rise-time. This is in line with the fact that rise-time is not fixed and that it is determined by the temporal distance between L and the segment boundary right before H. Moreover, the correlation between the rise-time and the duration of the segment with which H is aligned is low, as evidenced by the results given in (11).

(11) Pre-nuclear type: Rise-time and V_{cli}, $R^2 = .017, p = .42$ low correlation
Nuclear type: Rise-time and C_{post}, $R^2 = .041, p = .21$ low correlation
Focus type: Rise time and C_{post}, $R^2 = .0009, p = .85$ low correlation

This means that the alignment of H is not related to the duration of the segment with which this tone is aligned. So for instance, in a Focus AP, the H is always aligned early in the consonant following the stressed syllable (C_{post}), without the duration of that consonant playing a role in the alignment.

A related matter is the alignment of L, for which correlation analyses show the same trend as for that of H. The results are given in (12).

(12) Pre-nuclear type: LV1 and V_{pre}, $R^2 = .560, p < .0001$ high correlation
Nuclear type: LV1 and V_{pre}, $R^2 = .477, p < .0001$ high correlation
Focus type: LV1 and V_{pre}, $R^2 = .575, p < .0001$ high correlation
Pre-nuclear type: LV1 and C_{pre}, $R^2 = .040, p = .21$ low correlation
Nuclear type: LV1 and C_{pre}, $R^2 = .062, p = .12$ low correlation
Focus type: LV1 and C_{pre}, $R^2 = .005, p = .65$ low correlation

As can be seen in (12), the duration of the vowel preceding the stressed syllable (V_{pre}) is a good predictor of the alignment of L, but the duration of the following consonant (C_{pre}), with which L is aligned, is unrelated to it. So, L is aligned with C_{pre} (earlier for the Focus type and later for the Pre-nuclear type) without the duration of C_{pre} being relevant.

Also relevant to the targets vs. movements issue is the slope of the rise. If pitch targets rather than pitch movements are the primitives of Persian intonation, then there should not be any systematic relation between pitch excursion and rise-time. In other words, the slope of the rise should not be fixed, as would be in a framework where pitch targets play a secondary role to pitch movements. The correlation analysis supports this idea, as evidenced by (13),

[8] The coefficient of determination (R^2), which is computed by squaring the correlation coefficient (R), gives a clearer picture of the relation between the variables in good-sized samples (e.g. Graziano & Raulin 2004).

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which contains the results of correlation analysis between rise-times and normalized pitch excursions.

(13) Pre-nuclear type: Rise-time and excursion, $R^2 = .134$, $p = .02$ low correlation
Nuclear type: Rise-time and excursion, $R^2 = .073$, $p = .09$ low correlation
Focus type: Rise time and excursion, $R^2 = .002$, $p = .479$ low correlation

The above analyses together suggest that pitch targets are the fundamental building blocks of Persian intonation rather than pitch movements which are a function of their starting and ending points.

2.3.2 Gradient vs. categorical differences

The next issue concerns the status of Persian with regard to other attested languages (see section 1 above for a summary of alignment patterns in some languages). Although a precise comparison among languages is impossible (due to the differences in factors such as location of the pitch accent in the sentence, methodology, segment type, etc.), an overview reveals the following. In Persian Pre-nuclear APs, the alignment of L is very similar to the North German case (Atterer & Ladd 2004), i.e. midway in the consonant preceding the stressed vowel (C_{pre}), and that of H to the South German case (Atterer & Ladd 2004), i.e. into the post-stress vowel (V_{cli}). In Nuclear APs, the L is aligned early in the stressed syllable, similar to Lekeitio Spanish (Elordieta & Calleja 2005) and the H with the post-stress consonant (C_{post}), similar to German (Mücke et al. 2006). Such similarities are in line with Atterer & Ladd's (2004) proposal that the alignment differences among languages are continuous and not categorical. Regarding the differences between AP types and specifically the pre-nuclear/nuclear contrast, the alignment of H in Persian nuclear rises is earlier than that in pre-nuclear ones, similar to Greek (Arvaniti et al. 1998, 2006), Dutch (Ladd et al. 2000, Schepman et al. 2006), varieties of German (Atterer & Ladd 2004, Mücke et al. 2006), and varieties of Spanish (Nibert 2000, Elordieta & Calleja 2005). This brings us to the question of whether the possible differences ACROSS THE DIFFERENT AP TYPES in Persian are categorical and warrant different phonological representations or not. A logical prerequisite to this discussion would be to re-examine the appropriateness of the phonological representation of the Persian AP, i.e. a bi-tonal pitch accent consisting of an L and an H*.

There is an obvious rise pattern in Persian which can be characterized by a low followed by a high, both of which are aligned outside the stressed vowel. With regard to the relation of the L and H tones to one another and the location of the star in the representation of rises, researchers have taken different approaches. For instance, based on the fact that Greek pre-nuclear rises have their low and high aligned outside the stressed syllable, Arvaniti, Ladd & Mennen (2000) suggest five representation possibilities for the Greek pre-nuclear accents, namely L* + H, L + H*, LH, [LH]*, and L*H*, stating that their data are compatible with all five representations; or Atterer and Ladd (2004) show that British English, Dutch, Greek, Northern German, and Southern German all have the same type of targets – namely an L followed by an H – but exhibit subtly different patterns of alignment, and thus the authors abandon the idea of a starred tone (Elordieta & Calleja 2005 adopt the same view in their work on different varieties of Spanish). Given that the main aim of the present paper is to study the alignment patterns of the Persian AP, I will continue, in line with previous accounts of Persian intonation (e.g. Jun et al. 2003, Mahjani 2003), to consider the H tone as the starred tone and regard the Persian rise pattern as L + H*.

Now, let us address the question of whether the different AP types, i.e. Pre-nuclear, Nuclear, and Focus, motivate different phonological representations. The three types have been represented throughout the paper as L + H*h, L + H*l, and L + H*l, respectively. With regard to the Focus AP, as the results of this paper show, the mean pitch excursion of the Focus AP is greater than that of the other two types and significantly different from the Nuclear type. The Focus AP is pragmatically distinct from the other two types, in that it contains an

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element which is highlighted and used in contrast to other elements in the discourse. This suggests that this AP type might have a distinct underlying pitch accent. Following Jun et al. (2003), the possibility of the pitch accent L + ˆH* for Persian Focus AP is suggested here. The diacritic ˆ before H is used to denote extra high pitch and signifies the raised F0 in the Focus AP. Diacritics are used in intonational studies to mean both distinctive tonal targets and the phonetic realization of tonal targets; e.g. the diacritic ! has been used to show a distinctive pitch accent in English and German (H + !H*) and to denote a phonetic difference in Greek and Chickasaw (!H*) (Jun 2005). In the present paper, the diacritic ˆ is used in the former sense, i.e. as a marker of a phonological distinction.

The choice of a separate pitch accent for focus increases the number of Persian pitch accents and is a slight deviation from the two-target system; hence, it requires some justification. It might be argued that the extra high F0 characteristic of focus can simply be seen as part of the phonetic realization of focus. For one thing, the phonologically distinct representation of focus in Persian is cross-linguistically supported by the fact that in some languages or language varieties, focus is phonologically marked. Such is the case in Florentine Italian, Pisa Italian, Greek, and German, where speakers use a different or an additional pitch accent (Avesani & Vayra 2003, Gili Fivela 2004, Arvaniti et al. 2006, and Baumann et al. 2007, respectively), and Korean, where speakers use a different phrasing (Jun 1996). For instance, in Florentine Italian, non-contrastive focus is signaled by a bi-tonal pitch accent with a low target (H + L*), and contrastive focus is signaled by a high target, either a rising L + H* accent or a sustained high H + H* accent (Avesani & Vayra 2003); in Pisa Italian, the autosegmental representations for broad and narrow focus are H + L* and [L +]H* + L, respectively (Gili Fivela 2004); or in Greek polar questions, an L* tone must co-occur with the stressed syllable of the word in focus, making it phonologically distinct (Arvaniti et al. 2006). Another issue concerns the relationship between focus and pitch excursion. As Arvaniti et al. (2006) state, focus cannot be analyzed as a mere manipulation of pitch excursion. They show that the focused word in Greek polar questions is always associated with a final rise-fall movement, but the peak of this movement is aligned in different ways depending on the position of the nucleus: with the nucleus on the final word, the peak co-occurs with the utterance-final vowel (whether this vowel is stressed or not), and with the peak on an earlier word, the peak co-occurs with the stressed vowel of the last word. Arvaniti and colleagues conclude that focus and pitch excursion cannot be equated with one another, i.e. it cannot be said that focus is simply marked with an increase in pitch. This is backed up by the fact that other factors may be involved to signal focus more systematically than expanded F0, e.g. duration for Taiwanese Min (Pan 2007). Finally, as mentioned earlier, focus and non-focus APs are quite different in meaning and if the pitch accent for the two were identical, then this meaning difference could not be captured in the tonal representation. The foregoing discussion suggests that the relationship between pitch and focus is, in Arvaniti et al.'s (2006) words, 'part of the grammar' of Persian and hence is encoded in the phonology.

As for the distinction between Pre-nuclear and Nuclear APs, I argue that this difference need not be reflected in the pitch accent representation of the AP (namely, L + H*). The evidence for this claim comes from the fact that the choice between Pre-nuclear and Nuclear APs is directly related to the location of the AP in the sentence. As mentioned in section 1.1, it is always the last AP that is the nuclear AP, and being Nuclear or Pre-nuclear does not necessarily cause any semantic change. To clarify, consider the noun phrases in (14). As before, the nuclear AP is underlined.

(14) a.	AP (pre-nuclear)	AP (nuclear)	
	tʃahár-ta	dæftár.	
	four-CL	notebook	
	'Four notebooks.'		

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b. | AP (pre-nuclear) | AP (pre-nuclear) | AP (nuclear) |
tʃahár-ta dæftær-ɛ sæd-bærg.
four-CL notebook-LINKER hundred-sheet
'Four hundred-sheet notebooks.'

c. | AP (pre-nuclear) | AP (pre-nuclear) | AP (pre-nuclear) | AP (nuclear) |
tʃahár-ta dæftær-ɛ sæd-bærg-ɛ bozórg.
four notebook-LINKER hundred-sheet-LINKER large
'Four large hundred-sheet notebooks.'

In (14 a), *dæftær* 'notebook' is the head noun and the semantic core of the noun phrase, and it is the nuclear AP. In (14b), 'notebook' is post-modified with the adjective *sæd-bærg* 'hundred-sheet' and as a result, the status of 'notebook' has changed from nuclear to pre-nuclear, while it is still the head of the noun phrase and its main semantic element. The nuclear AP is the modifier 'hundred-sheet' now. In (14c), yet another modifier is added (*bozorg* 'large') resulting in the same change, i.e. the shift of the nuclear accent from 'hundred-sheet' to the final AP 'large'. So, the nuclear/pre-nuclear status of an AP has not affected its semantic load: the noun 'notebook' is nuclear in (14a) and pre-nuclear in (14b) and (14c), yet it is always semantically the most important element; also, the adjective 'hundred-sheet' is nuclear in (14b) and pre-nuclear in (14c), while in both, it is semantically secondary to 'notebook'. The foregoing discussion suggests that the Pre-nuclear and the Nuclear pitch accents in Persian are phonologically the same (L + H*). These two are, however, distinguished by their boundary tones: high for the former (L + H*h) and low for the latter (L + H*l). Hence, the three AP types can be represented as in (15).

(15) Pre-nuclear: L+H*h
Nuclear: L+H*l
Focus: L+H*l

In sum, the greater excursion of the Focus AP is reflected in the pitch accent (L + ˆH*) since this AP type is pragmatically distinct from the other two in that it highlights an element in contrast to others in the discourse. The difference between the Pre-nuclear and the Nuclear type is not caused by any change in meaning so there is no reason for them to have different pitch accents (both are L + H*); the two are distinguished by their boundary tone, which is high for Pre-nuclear and low for Nuclear APs.

Before closing the paper, there should also be a mention of the notion 'secondary association'. This concept, which is originally from Pierrehumbert & Beckman's (1988) work on Japanese tone structure, was later adopted by other authors, e.g. Grice (1995), Gussenhoven (2000), Grice, Ladd & Arvaniti (2000), Lickley, Schepman & Ladd (2005), Prieto, D'Imperio & Gili Fivela (2005), Welby (2006), and Face & Prieto (2007). Views of secondary association suggest that phonetic alignment of tones indicates different kinds of phonological representations, and that tonal targets of pitch accents have a primary association to stressed syllables but may also have a secondary association to (the edges of) prosodic constituents. Following this view, the Persian Nuclear AP might be seen as having the pitch accent L + H* which is primarily (or underlyingly) associated to the stressed syllable, and secondarily associated to the left edge of the stressed and the following syllable (for L and H, respectively). For the Pre-nuclear AP, L and H have secondary associations to the consonant preceding the stressed vowel and the vowel following the stressed vowel, respectively. To illustrate the concept of secondary association, a schematic representation of primary and secondary associations of the Persian Nuclear AP is given in figure 20.

In figure 20, the pitch accent has primary association to the stressed syllable and the individual tones have secondary associations to the consonants at the sides of the stressed vowel. As far as the goals of the present paper are concerned, the secondary

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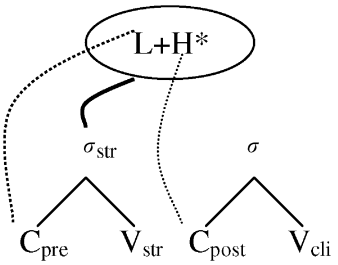

Figure 20 Schematic representation of primary and secondary associations in a Persian Nuclear AP (solid and dotted curved lines, respectively). σ_{str} denotes the stressed syllable.

association analysis does not seem to have a crucial advantage over the alignment view adopted here, since this analysis approaches tonal alignment from a phonological viewpoint, while the concern of the present paper has been to deal with the realizational properties of Persian intonation in a quantitative manner. For this reason, the view is not pursued any further.

3 Conclusion

The experiment in this paper revealed certain phonetic characteristics of the Persian Accentual Phrase (AP). Three types of cliticized APs were studied: pre-nuclear pitch accent high-boundary-toned APs, nuclear pitch accent low-boundary-toned APs, and focus (low-boundary-toned) APs. The results showed that the alignment of L is always in the consonant preceding the stressed vowel of the AP. The L occurs as early as the onset of this consonant in the Focus AP and goes as far as the middle of the consonant in APs with a high boundary tone. The alignment of H is directly related to the boundary tone of the AP. For APs with a high boundary tone, the H is aligned in the middle of the vowel of the clitic. For APs with a low boundary tone, it is aligned earlier: in the preceding consonant, which is the consonant after the stressed vowel. The overall alignment patterns in Persian rises show subtle differences with those in other attested languages, implying that these differences are gradient in nature. The vowels of the Focus AP are on average longer than those of the non-focused counterparts. The consonants preceding and following the stressed vowel are of the same duration in all three AP types. The duration of the Focus AP is significantly greater than the Pre-nuclear AP. The pitch excursion of the Nuclear type is significantly less than the Focus type. This is caused by the frequency of the H rather than that of the L. Among the AP types, the Focus AP is underlyingly different and pragmatically distinct from the other two types, suggesting the pitch accent L + ˆH* for focus constituents. The alignment of the L and the H and the variability of the duration and the slope of the rise in Persian suggest that in this language, tonal targets rather than pitch movements constitute the fundamentals of intonation, which in turn lends support to the appropriateness of the AM approach for studying Persian intonation.

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Appendix. The data used in the experiment

The test AP is italicized; the contrastively-focused AP is in capitals.

1. Pre-nuclear: diruz *maman-æm* umæd-ɛ-bud.
   yesterday mom-too come.PST-PTCP-be.PST.3SG
   'Yesterday mom had come too.'
   Nuclear: xanum-ɛ *maman-æm* bud.
   woman-DEF mom-my be.PST.3SG
   'That woman was my mom.'
   Focus: xanum-ɛ *MAMAN-ÆM* bud.
   'That woman was MY MOM.'

2. Pre-nuclear: sɛda-jɛ *nalæ-mun* ɛmruz dær+umæd.
   sound-LINKER whimper-our today PTC+come.PST.3SG
   'Our whimper was heard today.'
   Nuclear: sɛda-jɛ *nalæ-mun* bud.
   sound- LINKER whimper-our be.PST.3SG
   'It was the sound of our whimper.'
   Focus: sɛda-jɛ *NALÆ-MUN* bud.
   'It was the sound of OUR WHIMPER.'

3. Pre-nuclear: tozih-ɛ *kamɛl-i* mani næ-dad.
   explanation- LINKER complete-IND Mani NEG-give.PST.3SG
   'Mani didn't give a full explanation.'
   Nuclear: tozih-ɛ *kamɛl-i* dad.
   explanation- LINKER complete-IND give.PST.3SG
   'S/he gave a full explanation.'
   Focus: tozih-ɛ *KAMEL-I* dad.
   'S/he gave A FULL explanation.'

4. Pre-nuclear: ʃæhr-ɛ *milan-o* mænzur-æm næ-bud.
   city- LINKER Milan-SPEC intention-my NEG-be.PST.3SG
   'I didn't mean the city of Milan.'
   Nuclear: ʃæhr-ɛ *milan-o* mænzur-æm bud.
   city- LINKER Milan-SPEC intention-my be.PST.3SG
   'I meant the city of Milan.'
   Focus: ʃæhr-ɛ *MILAN-O* mænzur-æm bud.
   'I meant the city of MILAN.'

5. Pre-nuclear: mæn *æmin-o* mædrɛsɛ næ-did-æm.
   I Amin-SPEC school NEG-see.PST-1SG
   'I didn't see Amin at school.'
   Nuclear: mæn *æmin-o* mædrɛsɛ did-æm.
   I Amin-SPEC school see.PST-1SG
   'I saw Amin at school.'
   Focus: mæn *ÆMIN-O* mædrɛsɛ did-æm.
   'I saw AMIN at school.'

6. Pre-nuclear: diruz *namæ-mun* umæd.
   I letter-our come.PST.3SG
   'Yesterday our letter arrived.'
   Nuclear: mal-ɛ *namæ-mun* bud.
   property- LINKER letter-our be.PST.3SG
   'It was from our letter.'

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Focus: mal-ɛ *NAMÆ-MUN* bud.
'It was from OUR LETTER.'

7. Pre-nuclear: dær-ɛ *Gælæm-æm* indʒa bud.
cap-LINKER pen-my here be.PST.3SG
'The cap of my pen was here.'
Nuclear: dær-ɛ *Gælæm-æm* bud.
cap- LINKER pen-my be.PST.3SG
'It was the cap of my pen.'
Focus: dær-ɛ *GÆLÆM-ÆM* bud.
'It was the cap of MY PEN.'

8. Pre-nuclear: diruz *zæman-o* mænzur-æm næ-bud.
yesterday time-SPEC intention-my NEG-be.PST.3SG
'Yesterday I didn't mean the time.'
Nuclear: diruz *zæman-o* mænzur-æm bud.
yesterday time-SPEC intention-my be.PST.3SG
'Yesterday I meant the time.'
Focus: diruz *ZÆMAN-O* mænzur-æm bud.
'Yesterday I meant THE TIME.'

9. Pre-nuclear: væz-ɛ *mali-m-o* nadʒur kærd.
situation- LINKER financial-my-SPEC bad do.PST.3SG
'It made my financial situation awkward.'
Nuclear: væz-ɛ *mali-m-o* mænzur-ɛʃun bud.
situation- LINKER financial-my-SPEC intention-their be.PST.3SG
'They meant my financial situation.'
Focus: væz-ɛ *MALI-M-O* mænzur-ɛʃun bud.
'They meant MY FINANCIAL situation.'

10. Pre-nuclear: bɛlæxærɛ *tunɛl-o* monfædʒɛr+kærd-æn.
finally tunnel-SPEC exploded+do.PST-3 PL
'Finally they blew up the tunnel.'
Nuclear: mæn *tunɛl-o* diruz mi-goft-æm.
I tunnel-SPEC yesterday DUR-say.PST.1SG
'I was talking about the tunnel yesterday.'
Focus: mæn *TUNEL-O* diruz mi-goft-æm.
'I was talking about THE TUNNEL yesterday.'

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