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Acoustic correlates of lexical stress in Moroccan Arabic

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Abstract

Presently there is no consensus regarding the interpretation and analysis of the stress system of Moroccan Arabic. This paper tests whether the acoustic realisation of syllables support one widely adopted interpretation of lexical stress, according to which stress is either penultimate or final depending on syllable weight. The experiment reports on word-initial syllables that differ in presumed stress status. Target words were embedded in a carrier sentence within a scripted mock dialogue to ensure that the measurements reflect lexical stress rather than phrase-level prominence. Results from all four acoustic parameters tested (f0, duration, Centre of Gravity and vowel quality) showed that there were no differences as a function of presumed stress status, thus failing to support an interpretation according to which stressed syllables are acoustically differentiated. We consider the results in relation to previous claims and observations, and conclude that the absence of acoustic correlates of presumed stress is compatible with the view that Moroccan Arabic lacks lexical stress.

1. Introduction

The present paper presents a systematically controlled experimental investigation of correlates of lexical stress in Moroccan Arabic (MA)1. The status of lexical stress as present or absent in this language has been subject to some debate and is not currently resolved (see Maas 2013).

The first goal of this paper, therefore, is to contribute to this debate with a detailed study of the acoustic properties of presumed stressed and unstressed syllables, providing a type of evidence that has hitherto been absent from the discussion. The specific claim that is being tested is that stress is penultimate, unless the final syllable of the word is heavy, in which case stress is final (Benkirane 1998, see also Boudlal 2001).

The second goal of this paper is to once more make explicit that the investigation of lexical stress requires stimuli that isolate LEXICAL STRESS from PHRASE-LEVEL PROSODIC EFFECTS.[2] This confound is also seen in some of the existing literature on Moroccan Arabic stress and has led to claims that we will dispel with here. Specifically, acoustic correlates of stressed syllables in words produced in word lists do not reflect properties of lexical stress alone, but also of phrase-level pitch events such as the presence of a pitch accent on the stressed syllable, or durational enhancement in the form of accentual lengthening. The present experimental paradigm was designed to circumvent these effects and may serve as an example methodology for the investigation of acoustic correlates of lexical stress.

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[1] This paper is in part based on the first author's doctoral dissertation (Bruggeman 2018: Chapter 4).
[2] We are far from alone in making this observation (among many others, Beckman & Edwards 1994, van der Hulst 2014a, Athanasopoulou & Vogel 2016, Roettger & Gordon 2017). The idea that stressed syllables may derive some of their properties from postlexical prosody goes at least as far back as Fry (1955, 1958). Nevertheless, despite the fact that this is currently widespread knowledge (Fry 1955 and Fry 1958 each have 1000+ hits on Google scholar, July 2019), there is much recent work that does not distinguish between lexical stress and phrasal prosodic effects.

The structure of this paper is as follows: Section 2 provides a general background to this study, with Section 2.1 highlighting relevant aspects of the experimental study of stress. Section 2.2 introduces Moroccan Arabic, and Section 2.3 gives an overview of what is currently known about its lexical phonology. Section 2.4 reviews prior claims about lexical stress and its interaction with intonation, and Section 2.5 presents the aim of the experiment and some predictions. Section 3 outlines the methods of the experiment, and Section 4 the results, with each of the four acoustic correlates tested (f0, duration, spectral Centre of Gravity, vowel quality) treated separately. Section 5 forms the discussion and Section 6 concludes the paper.

2. Background

2.1. Methodological issues in the identification of lexical stress

This section serves to review a number of theoretical issues relevant to the identification and investigation of stress in general. The next section then addresses how the present experiment furthers the debate about stress in MA.

The first issue relates to the general definition of stress, as it is well known that stress is defined differently in different sources (see van der Hulst 2014a). The most important distinction is between the definition that takes stress to refer to perceived or ‘actual’ prominence (Ladd 2008: 53), and the definition that takes stress to refer to an abstract property that differentiates one syllable in a word from the others, where stress is typically considered to be part of a word’s lexical entry. It is this latter definition of stress which is adopted here (in line with Hayes 1995: 8; Gussenhoven 2004; Ladd 2008: 50f.; Goedemans & van der Hulst 2013; Hyman 2014: 56).[3]

The second issue relates to how stress is typically diagnosed (see Hayes 1995), which may include a variety of strategies such as native speaker judgments, the differential status of stressed syllables with respect to phonological rules, and, as one of the most widely used diagnostics, the relative acoustic enhancement of stressed syllables. This latter diagnostic is, however, rather problematic. First, there is no one-to-one mapping between actual (acoustic) prominence and stress, and secondly, the interpretation of null results for acoustic enhancement may present a difficult rhetorical task.

The first problem with acoustic enhancement (specifically the (mis)identification of acoustic enhancement as lexically specified inherent, phonological prominence) is best explained by the observation that stress and actual prominence are not characterised by a one-to-one mapping: acoustic prominence does not equal stress and stress does not equal acoustic prominence.

The first of these statements (acoustic prominence does not equal stress), comes down to the observation that such prominence may result from postlexical intonational movements. When these take the form of pitch accents that associate with a stressed syllable, the correct syllable might still be identified as stressed, but the enhancement should nevertheless be attributed to the pitch accent rather than to stress itself (with stress status by definition persisting irrespective of whether or not a given instance of that syllable carries a pitch accent) (see Gordon & Roettger 2017). However, not all intonational prominence reflects pitch accentuation, and acoustically and perceptually salient movements such as those at phrase boundaries may co-occur with unstressed syllables. Unfortunately, the acoustic enhancement resulting from intonational movements such as final rising f0 observed in list-based elicitation has often been

[3] In fact, some sources (e.g. Abercrombie 1976 in van der Hulst 2014a, Hyman 2014) call this particular property ‘accent’ instead. Despite the terminological quibble, the existence (in many languages) of a property designating culminative lexically specified prominence is uncontroversial.

mistakenly identified as a correlate of lexical stress proper (see Section 2.4.1 for specific reference to Moroccan Arabic).

For the second of these (stress does not equal acoustic prominence), stressed syllables are not necessarily acoustically enhanced in all languages. Firstly, there is a lot of variation, with different languages using different acoustic parameters to mark stressed syllables. Many, though not all, use duration, while others also differentiate syllables in terms of spectral tilt, intensity or more extreme formant values for vowels (for a critical overview see Gordon & Roettger 2017). The role of intensity or f0 alone in cueing stress remains controversial, the former because it is highly correlated with f0 and other spectral characteristics (Lehiste 1970), and the latter because of its role in signalling postlexical prominence. Secondly, some languages may not at all reliably or perceptually differentiate stressed syllables. For example, in Hungarian, in which stress is uncontroversially word-initial, intensity may be the only correlate (Varga 2002, Szalontai et al. 2016). The existence only of subtle intensity differences casts doubt on whether stress is perceptually retrievable in Hungarian. In sum, the presence or absence of acoustic enhancement of (presumed) stressed syllables should not be taken, on its own, to provide conclusive evidence about the existence of stress in a given language.

The second reason why acoustic enhancement of stressed syllables is a problematic diagnostic concerns a more general interpretative complication. Specifically, if an experiment does not find any acoustic correlates to stress, this does not prove that stress in general is absent: Negative evidence cannot be taken to support a null hypothesis. It is therefore very difficult to show that lexical stress is absent in a given language. A most convincing approach with this aim would have to accumulate results from various diagnostics to stress and show that they all converge in failing to provide evidence in favour of the existence of stress.

The present article will contribute to the debate about the existence of lexical stress in Moroccan Arabic by investigating the acoustic enhancement of presumed stressed syllables, and relate findings to what is currently known about other diagnostics to stress in Moroccan Arabic.

2.2. Moroccan Arabic within the Arabic-speaking world

Before reviewing previous work on the Moroccan Arabic phonological system, including stress, this section will relate Moroccan Arabic to other varieties of Arabic. Moroccan Arabic denotes a variety of Arabic that is strictly spoken, and in this article it refers specifically to the Moroccan variety spoken in Casablanca. Morocco is characterised by a high degree of multilingualism, with many speakers being bilingual in Berber and Moroccan Arabic, and many also proficient in Modern Standard Arabic (MSA) as well as French and/or Spanish, depending on the region. The multilingual character of Moroccan society is further enhanced by the diglossic situation that characterises all modern Arabic-speaking societies, involving varying registers of Arabic ranging from local varieties of Moroccan Arabic to the supranational Standard Arabic, i.e. MSA (for the situation in Morocco specifically see Maas & Procházka 2012; for diglossia in the Arabic-speaking world in general see chapters in Owens 2013, Versteegh 2014). To the extent that a national variety of Moroccan Arabic can be identified, it is clear that it differs considerably from Modern Standard Arabic (Mitchell 1993, Maas & Procházka 2012). Moroccan Arabic is not intelligible to speakers of most other varieties of Arabic, and its many divergent phonological characteristics are usually traced back to extended and intensive contact with various Berber languages (Mitchell 1993, Heath 1997, Dell & Elmedlaoui 2002, Maas 2019). In fact, Moroccan Arabic and (Tashlhiyt) Berber have been said to exhibit similar 'surface phonologies' (Dell & Elmedlaoui 2002: 227). In this context it is worth pointing out that Tashlhiyt Berber specifically is considered to lack lexical stress (Stumme 1899, Dell & Elmedlaoui 2002, Roettger, Bruggeman & Grice

2015, Roettger 2017, Bruggeman 2018), although the absence of lexical stress is possibly also a feature of other varieties of Northern Berber (Kossmann 2012).

Lexical stress has been investigated in many varieties of Arabic other than MA. Phonetic investigations have been conducted on several varieties, with results typically supporting native speakers' intuitions about stress positions, including Egyptian and Jordanian (Almbark, Bouchhioua & Hellmuth 2014), Lebanese (Chahal 2003) and Tunisian (Bouchhioua 2008; see also Ghazali & Bouchhioua 2003). Several more varieties are subject to ongoing work (based on the Hellmuth & Almbark 2017 corpus).[4] Work using Metrical Stress Theory adds a number of varieties to this list, with at least nine synchronic varieties reported to have stress in Hayes (1995) alone. In most varieties of Arabic stress assignment is subject to weight and position, with stress typically targeting a final superheavy syllable (e.g. CVCC), or, in the absence of such a syllable, a penultimate heavy syllable (e.g. CVː) (Watson 2011).

2.3. Moroccan Arabic lexical phonology

2.3.1. Syllable structure

Most Arabic varieties distinguish between phonologically heavy and light syllables, where the presence of a coda or a long nucleus results in a heavy syllable (e.g. Watson 2011). Assuming that Moroccan Arabic does not have a vowel length distinction (see Section 2.3.2), the number of consonantal slots in the coda determines the weight of the syllable as light (e.g. CV), heavy (e.g. CVC), or, under some analyses, superheavy (e.g. CVCC). CəC syllables are typically considered light (Dell & Elmedlaoui 2002).

Moroccan Arabic syllable structure has been investigated in great detail, resulting in varying claims (Benhallam 1980, 1990; Benkirane 1982; Dell & Elmedlaoui 1985, 2002, 2008; Boudlal 2001). What is clear from all sources is that MA allows for more complex consonant clusters than most other varieties of Arabic, while the representation of these clusters in terms of branching or simplex onsets and codas remains disputed. For example, Benkirane (1998) lists a number of syllable types including CV, CCV, CCVC, and CCəCC, while Dell & Elmedlaoui (2002) argue that syllable onsets cannot be branching, and that codas can be branching only if they consist of geminates. In order to account for what seem to be syllable-initial clusters, Dell & Elmedlaoui (2002) instead propose a complex general syllabification algorithm that posits onsetless syllables and empty nuclei.

What is important is that a distinction is made in all works on MA between heavy and light syllables, and sometimes superheavy syllables. The degree of consensus is limited to CV being considered light and CVC(C) heavy (with the exception of CəC). The stimuli used in the present experiment reflect only this uncontroversial distinction between light syllables on the one hand and heavy/superheavy syllables on the other hand.

2.3.2. Vowel inventory

Various claims have been made about the vowel system in Moroccan Arabic. On some accounts MA has a five-vowel system consisting of /iː ə aː ʊ uː/ (Hamdi 1991 as cited in Al-Tamimi 2009, 2017). Most researchers however posit only three or four vowels, namely /i a u/ plus a central vowel (Benkirane 1998, Boudlal 2001, Dell & Elmedlaoui 2002). The central vowel is usually considered non-phonological, serving primarily to break up illicit consonant clusters (e.g. Dell & Elmedlaoui 2002). In addition to the number of vowels, the representation of length is also a matter lacking consensus, as can

[4] The reported correlates of 'stress' in De Jong & Zawaydeh (1999) on Jordanian Arabic are likely to be subject to the lexical/postlexical prosody confound.

be judged from the juxtaposition of the phonological categories /i˘/ and /i/, and /u˘/ and /u/ by the aforementioned sets of authors. This might be caused by the existence of a surface contrast in length, with CVC syllables having longer vowels than CV syllables (Benkirane 1982, Dell & Elmedlaoui 2002, Yeou 2005). Despite disagreement about the correct representation of length, it is widely acknowledged that MA lacks a phonological vowel length distinction for vowels with the same place of articulation, which sets MA apart from most other varieties of spoken Arabic.

This is backed by the absence of minimal pairs of the type /sin/ 'tooth' ~ /siːn/ 'the letter "sin"' (example from Iraqi Arabic, Al-Ani 1970). It will be assumed here that the phonological vowel inventory of MA can be represented as simply /i a u/, with an additional centroid vowel which may be either phonological /ə/ or phonetic [ə].

2.4. Earlier work on Moroccan Arabic stress

2.4.1. Proposed stress generalisations

As previously mentioned, it is currently not clear whether MA has lexical stress. In most teaching materials for Moroccan Arabic no reference is made to lexical stress (including Harrell 1962, Harrell, Abu-Talib & Carroll 1965, Andjar, Bacon & Benchehda 2014, Peace Corps 2016, although accent assignment rules are given in Hoogland 2017). At least one dictionary does not indicate stress in the entries (Harrell & Sobelman 2006).[5] Highly informative also is the review found in Maas (2013), who discusses more than 10 sources published between 1894 and 2008 that all differ to some extent in their views on the existence of word prominence in this language. Unfortunately, most of the reviewed sources are not fully clear on the phenomenon being discussed, as reflected in the choice of terminology, which includes 'Wortakzent', 'Akzent' and 'Accent' (by German authors), 'accent' and 'accent de mot' (in French works), 'accento tonico' (in Italian) and 'stress' (in English). Some of these terms are perhaps best interpreted as referring to postlexical pitch prominence rather than lexical stress, while others do in fact seem to refer to inherent word-level prominence. In reviewing the evidence in detail, Maas (2013) argues that the various positions can be allocated to two main groups: one group assumes that Moroccan Arabic has word stress, although what kind of stress remains unclear (including El Mejjad 1985, Benhallam 1989; both cited in Maas 2013); the other group considers MA to lack word stress (Stumme & Socin 1894, Brockelmann 1908, Fischer 1917, Cantineau 1960, Durand 1994, Aguadé 2008).

In addition to the sources reviewed by Maas (2013), there are further proponents of the existence of word stress who posit specific stress rules and generalisations. These include, notably, Benkirane (1998), according to whom stress falls on the final syllable if it is heavy (i.e. a closed syllable such as CVC) and on the penult otherwise. This position is shared by Nejmi (1993, as cited in Boudlal 2001) and in part by Boudlal himself (see next paragraph). Others assume a fixed position for stress, such as final stress ('final prominence' in Watson 2011), or penultimate stress (e.g. Benhallam 1989, as cited in Maas 2013). Yet others argue for a more variable stress position that may target syllables prior to the penultimate (El Hadri 1993 as cited in Boudlal 2001).

Finally, one particularly complicated picture is sketched by Boudlal (2001: 99), who posits that 'the location of stress depends on whether or not the items considered occur in isolation or in context'. Accordingly, stress would be final when words are produced in context, but words in isolation would

[5] This is in contrast to at least some dictionaries for other varieties, such as the LisaanMasry dictionary for Egyptian Arabic (Green 2016). However, as a reviewer points out, it remains a possibility that the absence of stress marking follows from the predictability of the system (although with the various opinions on what the stress system is there would be several candidate rules).

be captured by Benkirane's generalisation. This is in fact in line with Mitchell's (1993: 202) observation that 'the place of prominence in a word in isolation is not carried over to its occurrence in the phrase and sentence. It is only in phrase- or sentence-final position in unemphatic affirmative sentences that the pattern of the word-isolate may be repeated, and then by no means certainly'. Assuming that lexical stress is an invariant property of a word, reflected in its 'dictionary entry' (Abercrombie 1976 in van der Hulst 2014a:5), the very fact that the 'stress' or prominence location in a word may vary suggests that the phenomenon in question is not lexical stress but rather postlexical intonational prominence. Boudlal's (2001) interpretation of MA having final lexical stress on words produced in isolation is in fact readily interpreted as reflecting postlexical prosody. As Boudlal (2001) notes, final syllables of words produced in isolation are marked by 'high' (rising-falling) f0, which is the main reason why these syllables are considered stressed. This final rise-fall is not consistently present on words produced within a sentence, suggesting that the pitch movement at the right edge of words produced in isolation reflects an Intonational Phrase (IP-)final pitch effect. Words were in fact read aloud from a list, which strongly suggests that Boudlal's right-edge high pitch reflected a continuation rise or list intonation.

2.4.2. Native speaker perception of stress

The inconsistent analyses of word stress are matched by equally incongruous judgments on the position of word stress by native speakers. A number of studies, reviewed in Boudlal (2001), investigate where the main perceptual prominence of a word lies (El Hadri 1993, Fares 1993, Nejmi 1993, all as cited in Benhallam 1990, Boudlal 2001). In addition, Boudlal (2001) himself provides a study of his own. In all of these studies, participants were asked to indicate what they think is the most prominent syllable for words presented in written form in a list. While the authors propose different analyses of stress assignment in MA, all studies have in common that they find a great deal of disagreement between participants on the location of stress for any given word. For example, Boudlal (2001) found that the word *limun* 'oranges' was judged to have initial stress by 23 participants and final stress by 11 participants, while the numbers for *likum* 'for/to you' were 16 and 18, respectively. In any of the aforementioned stress assignment scenarios these two words would be expected to behave the same.

There are several difficulties in comparing and interpreting the results of these studies. Firstly, varying interpretations by the authors might in part be due to the different types of words and items tested. Fares (1993, as cited in Boudlal 2001) tested nouns and conjugated verbs, El Hadri (1993, as cited in Boudlal 2001) tested conjugated verbs only, some with affixes, while Benhallam (1990) and Boudlal (2001) tested cliticised forms in addition to all of the aforementioned forms. While an adequate description of stress in a language should be able to account for all types of words, it is possible that the varying morphological structure of words impacted on the different authors' identification of general patterns. A second problem is that the studies might have tested potentially different stress systems in the first place: Judgments reported by El Hadri (1993) and Fares (1993) came from speakers of Tetouan Moroccan Arabic. This variety has a somewhat differing vowel system from Casablancan Moroccan Arabic, which was the native variety of subjects in some of the other studies (Boudlal 2001).

Another type of difficulty relates to the variety of Arabic that was being responded to. Many of the words tested were typical Moroccan Arabic, but not all. Disagreement between native speakers might therefore in part be due to the fact that written Arabic is strongly associated with Modern Standard Arabic. Most if not all participants in the aforementioned stress identification studies were university students, which increases the likelihood that their judgments are influenced by their (good) knowledge of MSA. Despite the existence of prescriptive rules for MSA, it is not clear that it has a fixed stress system, since MSA is known to exhibit prosodic features of the national/regional varieties of the speaker (Benkirane 1998). Since each native variety of Arabic has its own, slightly different rules for stress assignment, the association of MSA with written stimuli might have unpredictable effects on stress judgments by MA speakers.

In short, there are several possible explanations as to why MA stress defies a clear analysis when the analysis is based on native speaker judgments. Nevertheless, the fact that several independent studies each found that judgments differ considerably between participants, and the fact that such disagreement exists in the first place, are in line with other indications that word stress in this language is rather elusive.

2.4.3. The role of stress in the intonation system

To date there is only a handful of sources discussing aspects of MA intonation. The most comprehensive treatment is Benkirane's (1998) qualitative analysis which involves a concise inventory, in INTSINT style (International Transcription System for Intonation, Hirst & Di Cristo 1998a), of the prosodic properties that are characteristic of various sentence types, including yes–no questions, declaratives, imperatives and question word questions.[6]

His characterisations are based on sentences read by various speakers combined with his own observations as a native speaker. In essence, Benkirane's claim about the interaction between stress and intonation is that sentence accent (nuclear pitch accent) targets the stressed syllable of the final word. He adds to this that in non-final words, stressed syllables are not differentiated in terms of pitch pattern (Benkirane 1998: 349).

A small set of experimental works on MA intonation paints a somewhat more complicated picture. Yeou, Embarki & Al-Maqtari (2007) compare the prosodic marking of contrastively focused words in a sentence context in Moroccan Arabic with two other varieties of Arabic.[7] Assuming the same stress assignment rule for all three varieties, the authors find that in each variety, contrastive focus is marked by the presence of a rising-falling pitch contour on the relevant word (and it is taken for granted that within the word it aligns with the stressed syllable). However, when we consider the few contours they provide as examples, it appears that MA might use rising-falling contours that are less localised to the 'stressed' syllable than in other varieties.

Yeou et al.'s (ibid.) interpretation, which might be summarised as 'pitch-prominence-goes-to-stress' contrasts with Burdin et al.'s (2015) claims. These authors look at the way different types of focus are realised within the noun phrase (in MA: a noun followed by an adjective). Their findings fail to support that focus is marked with pitch prominence in MA, as the location of pitch prominence in the noun phrase does not correspond to the intended location of focus. Secondly, they fail to find evidence in favour of the standard view in the literature that prominence-marking pitch events (in this case something like a focus marking pitch accent) seek out stressed syllables; the presumed stressed syllables do not attract pitch movement, and any pitch movement they find is analysed as constituent edge-marking. These authors consequently argue that MA marks focus by means of phrasing only, and lacks pitch accents altogether.

Finally, a middle way is taken by Hellmuth et al. (2015), who look at question prosody in yes–no questions. These authors observe that the alignment of the rise-fall that consistently marks the right edge of questions is not fully predictable either with reference to the right phrasal edge or the stressed

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[6] A second general source is Maas's (2019) corpus-based work, which describes on a case-by-case basis examples of sentences spoken in a naturalistic context. This work, however, does not make explicit mention of correspondences between possible lexical stresses and prosodic events.

[7] The same dataset is reported on, with a slightly different focus, by Yeou, Embarki, Al-Maqtari & Dodane (2007).

syllable alone (stress assignment following Benkirane 1998). Instead, the rise-fall is aligned with reference to both of these domains simultaneously, in that it aligns consistently with the final foot of the phrase-final word.

In sum, given a small body of work on the topic, the correspondence between lexical and stress and the location of pitch prominence in MA is anything but straightforward. The language clearly has rising-falling pitch movements in some contexts, but how exactly these align with the segmental string, including the possible attractor role of specific syllables (stressed or not), remains to be investigated. Section 4.1, which discusses the f0 properties of the present data, will return to this issue.

2.5. Aim of experiment and predictions

The preceding discussion has highlighted that there is presently no consensus regarding the existence of lexical stress in Moroccan Arabic. Among those who posit the existence of stress, there is moreover no agreement regarding the specific stress generalisation that would capture its assignment. In this paper, we test the most widely held assumption about Moroccan Arabic stress, namely that it is weight-sensitive (as in other varieties of Arabic) and targets either the penultimate or the final syllable (Benkirane 1998, Boudlal 2001). Recent work adopting or testing this view on MA stress includes Yeou, Embarki & Al-Maqtari (2007), Burdin et al. (2015) and Hellmuth et al. (2015).

We report on an experiment that tries to find acoustic correlates of stress as manifested in seven target syllables. Specifically, the experiment contrasts syllables as a function of presumed stress status. Since the hypothesis that is tested involves the stress-by-weight principle, all target syllables are light /CV/ syllables in word-initial position in disyllabic words. Each syllable occurs in two target words, once as presumed stressed and once as presumed unstressed, as a function of the weight of the final syllable (e.g. *mu* being stressed *ˈmuka* ‘owl’ and unstressed in *muˈkat* ‘owls’). In the following, these syllables will be referred to simply as stressed and unstressed, even if their status is based on a hypothesis.

The expectation is that if there is word-level stress, presumed stressed syllables should be differentiated in terms of their acoustic properties, in terms of durational, vowel quality and/or spectral properties. A large amount of literature on the topic leads us to hypothesise that under stress, syllables exhibit enhancement and may have (i) longer duration and (ii) more peripheral vowel quality. Spectral properties are likely to differ, too, but the direction will depend on the vowel in question. The expectation for f0 however is the absence of an effect, as the elicitation context was designed to avoid the presence of postlexical pitch events of any kind on the target syllable (see Section 3.3), and few, if any, studies have convincingly shown that f0 is a correlate of lexical stress proper, i.e. in the absence of postlexical pitch prominence (Gordon & Roettger 2017). We are therefore presenting f0 results mainly for the sake of completeness.

3. Method

3.1. Participants

Participants were recruited among students of the Université Hassan II in Casablanca, where they were also recorded. Two groups of speakers were recorded, each with an equal gender division. The first group consisted of 12 native speakers of Moroccan Arabic who grew up with Arabic only at home (the ‘monolingual’ group).[8] These speakers were aged between 21 years and 34 years. Ten of them were

[8] Quotation marks are used because these speakers were not in fact monolingual. All participants were fluent in two or more other languages, including Modern Standard Arabic and French. For ease of reference, however, the terms monolingual and bilingual are used to distinguish participants in terms of their first, home language status (Moroccan Arabic versus Moroccan Arabic and Tashlhiyt).

born in Casablanca and had lived there all their life, one speaker moved to Casablanca at the age of 2 years, and one speaker was born in nearby Kenitra.

The second group consisted of 12 speakers of Moroccan Arabic who were also native speakers of Tashlhiyt Berber through one or both parents (the ‘bilingual’ group). The choice to include bilinguals served to explore the possibility that their production of stress patterns in Moroccan Arabic might be different from that of the monolinguals due to the fact that Tashlhiyt lacks lexical stress (see Section 2.2). The ages of participants in this group ranged between 20 years and 32 years. Nine speakers in this group were born in Casablanca, the other three moved to the city at the respective ages of 6, 12 and 14 years. All 24 participants were also fluent in Modern Standard Arabic and French, and had received a number of years of English instruction in school.

3.2. Procedure

The present experiment was conducted as part of a larger recording session for the Intonational Variation in Arabic (IVAr) corpus (Hellmuth & Almbark 2017). For the present experiment participants were recorded individually in a quiet university room at the Université Hassan II. Recordings were made with a Shure SM-10 headset microphone.

Participants were first given oral instructions by a native speaker of MA (one of the authors) as to what the task entailed. They then received a printout of the experimental stimuli, consisting of 60 mini-monologues containing one target word each (see next section). There were no practice items in order to minimise the duration of the session as a whole, but there were three fillers at the top and bottom of each of the stimuli sheets. There was one mini-monologue for each target word and no repetitions. Participants read these monologues out loud in full at their own pace, and this part of the recording session took approximately five minutes.

3.3. Speech materials

The experimental design is based on the paradigm first used in Bouchhioua (2008) and subsequently in Almbark et al. (2014). The experiment contrasts identical initial syllables in disyllabic words that are hypothesised to form a minimal stress pair according to the aforementioned weight-sensitive interpretation of MA stress, such as *mu* in ˈ*muka* ‘owl’ and *mu*ˈ*kat* ‘owls’. The experiment tested the initial syllables of 12 word pairs that were chosen on the basis of their comparability in the full range of dialects used in the IVAr database. Among these, seven word pairs exhibited the MA stress contrast as per Benkirane’s (1998) generalisation (Table 1) and were analysed for this paper. The observed MA pronunciation columns reflect a broad phonetic transcription.[9]

	Hypothesised penultimate stress				**Hypothesised final stress**			
Syllable	**Stimulus**	**Transliteration**	**Observed MA pronunciation**	**Gloss**	**Stimulus**	**Transliteration**	**Observed MA pronunciation**	**Gloss**
ba	باشر	baʃar	/ˈbaʃər/	‘he preached’	باشرت	baʃarr	/baˈʃərt/	‘I preached’
ma	مَرَّة	marra	/ˈmərˤːə/[i]	‘one time’	مرّرت	marrart	/maˈrːərt/	‘I passed’
mu(k)	موكة	muka	/ˈmuka/	‘owl’	موكات	mukat	/muˈkat/	‘owls’
mu(rː)	مُرَّة	murra	/ˈmərːa/	‘bitter’	مرّين	murrin	/muˈrːin/	‘passers-by’
sa	سادة	sada	/ˈsadə/	‘plain’	سادات	sadat	/saˈdat/	‘gentlemen’
si	سيرة	sira	/ˈsirə/	‘path’	سينات	sinat	/siˈnat/	plural of letter ‘sin’
su	سورة	sura	/ˈsˤurˤə/[ii]	‘verse’	سودان	sudan	/suˈdan/	‘Sudan’

Table 1 Target syllables and their carrier words. For both /mu/ syllables the consonant at the onset of the next syllable is given in brackets to distinguish between the word pairs.

i. The transcription of the intended stressed syllable containing a schwa is unproblematic as there is no reason why a central vowel would theoretically be banned from being stressed in Moroccan Arabic (as opposed to in e.g. Germanic). Here its use reflects both native speaker intuitions and the authors’ auditory impression that the vowel sounds different from [i a u].
ii. The pharyngealisation in sura was unexpected given the written stimuli that lacked pharyngealisation. In any case, this word still forms a near-minimal pair with its counterpart Sudan.

[9] The transliterated forms are also the in-text forms.

Of the seven target syllables, five have an identical segmental environment across the stressed/unstressed conditions (*baʃar*/*baʃart*, *marra*/*marrart*, *muka*/*mukat*, *saada*/*saadat*, and *murra*/*murrin* although the latter pair does exhibit a vowel difference in the second syllable). *sira*/*sinat* and *sura*/*Sudan* have a different intervocalic consonant in the two stress conditions, so it should be noted that there might be segmental coarticulatory effects that could result in acoustic differences between the stress conditions.

The aim for these two word pairs, then, is to find observable acoustic enhancement in the expected direction (stressed syllables being enhanced) that cannot be explained by segmental effects.

Target words were placed in a carrier sentence which was in turn embedded within a short scripted monologue consisting of a total of three sentences, given below (second line representing MA pronunciation):

Context sentence 1
كلمة سهلة [target]
[target] kəlma sahla
[target] word easy
'[target] is an easy word'
Context sentence 2
كتب [target] جوج مرّات
ktəb [target] ʒuʒ mər:at
write.IMP [target] two times
'write [target] twice'
Target sentence
عاود [target] جوج مرّات
ʕawd [target] ʒuʒ mər:at
repeat [target] two times
'repeat [target] twice'

Stimuli were presented in Arabic script. As Moroccan Arabic is not usually written (Arabic script almost exclusively being used for Modern Standard Arabic), participants were explicitly instructed to produce Moroccan Arabic when reading the stimuli. Many of the lexical choices (e.g. *ʕawd* 'repeat.IMP', *ʒuʒ* 'two'), including some of the target stimuli, are used exclusively in Moroccan Arabic. For any words also used in Standard Arabic (such كلمة 'word') Moroccan renderings were used, e.g. *kəlma* (Standard: *kalima*). Auditory impressions by two of the authors (native Arabic speakers) confirmed the authentic Moroccan Arabic nature of the speech thus produced.

Target words' embedding in a sentence which in turn formed part of a larger context served to minimise the possibility that the target words carried postlexical prominence. Specifically, target words were (i) pragmatically given, as they are mentioned in both preceding context sentences, and (ii) postfocal, occurring immediately following *ʕawd* 'repeat!', which is contrastively focused due to the occurrence of *ktəb* 'write!' in the immediately preceding sentence (the imperative *ʕawd* was moreover presented in boldface). Finally, target words occurred in non-IP-final position in order to avoid phrase-final lengthening effects. An example spectrogram and waveform are given for one mini-dialogue in Figure 1 with the target word *muka* 'owl'. Note that only the third occurrence of the target word is being analysed in the rest of this paper.

In the target phrase (rightmost) the target word *muka* does not receive any pitch prominence in contrast to in the preceding two phrases. Specifically, it occurs after the main pitch event on contrastively focused ʕ*awd*, and it also is not subject to edge-marking pitch prominence (judging from the absence of pausing and/or pitch reset). This situation matches the intended context, allowing for the examination of correlates of stress in the absence of postlexical pitch prominence. As mentioned previously, therefore, we do not in fact expect to find an effect for f0 irrespective of whether lexical stress in MA exists or not (considering that f0 is an uncommon marker of word-level stress).

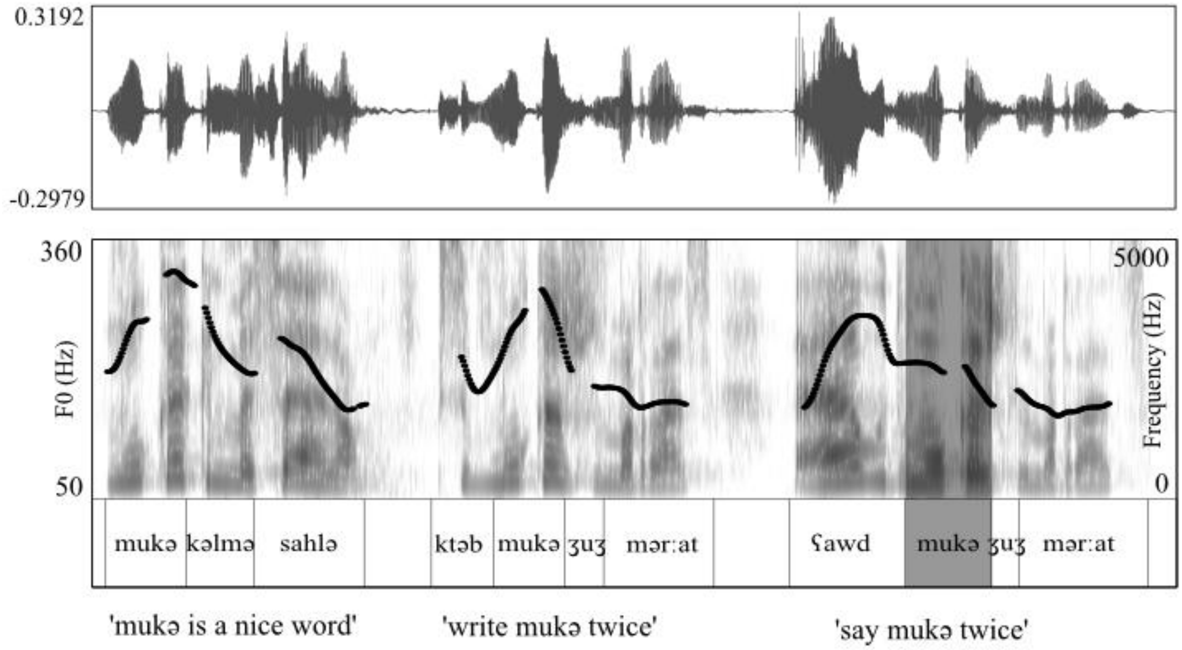

Figure 1 Example waveform, spectrogram and pitch track for one mini-monologue with the word *muka* 'owl', as spoken by a female speaker (IVAr filename: moca-slb3-f5). Shaded occurrence of *muka* is the target token analysed.

3.4. Analysis

3.4.1. Data processing and measurements

The acoustic parameters analysed were f0, duration, spectral Centre of Gravity, and vowel quality. Annotation (in Praat, Boersma & Weenink 2015) proceeded as follows: Automatic segmentation of utterances into words and segments was performed by means of the Prosodylab Aligner algorithm (Gorman, Howell & Wagner 2011). The segmentation of target words was then manually checked and corrected where needed, and coded for preceding and following pauses (preceding/following/none/both). Pauses were defined as periods of silence in the signal. They were identified on the basis of the auditory impression of a pause, supported by visual inspection of speech discontinuity in the spectrogram. The theoretical number of target items was N = 336 (2 speaker groups × 12 speakers × 2 stress conditions × 7 target syllables). Of these, N = 317 were targetlike (the intended word being produced without disfluencies; bilinguals N = 165, monolinguals N = 152). With respect to pausing, the most frequent location for pause insertion was following the target word (N = 86; an additional N = 4 had a preceding pause, and N = 6 had both). N = 221 items were produced without any pauses. Pausing is included as a binary predictor in the models detailed below (pause presence yes/no).

F0 measurements (in semitones) are based on a handcorrected version of the output of the standard pitch-tracking algorithm in Praat. Manual correction was limited to pitch-tracking errors, such as octave jumps and the tracking of pitch in cases of phonetically voiceless segments. Several static f0 measures were taken: Mean f0 throughout the target vowel, maximum f0, and f0 at intensity peak, with all measures additionally being converted to z-scores. Models were run on all measures, and on absolute as well as z-scored values. As the results were very similar in all cases the absolute mean f0 values only will be reported. To allow for a more holistic and dynamic analysis of f0 movements, phrasal f0 contours were extracted by means of measuring f0 at 20 equally spaced timepoints throughout each word, apart from target words, in which 10 points were measured per syllable (also 20 in total).

For duration, measurements of target vowels as well as syllables were taken. Vowel duration was determined as the period of time following the initial consonant with strong energy across the second and third formant. For the segmentation of intervocalic /r/, the onset of the /r/ was determined as the start of the (first) closure (virtually all /r/s were realised as either trill or tap). Statistical models were run on both absolute and z-scored values. When results between measures (vowel/syllable, absolute/z-score) are similar, only results for absolute vowel duration are reported. In cases of discrepancies in significance between models these are reported.

Spectral balance was measured to reflect the energy distribution across the vowel. If the aim is to characterise the loudness of a segment or syllable as a possible indicator of stress, spectral balance characteristics such as those termed 'spectral tilt', 'spectral slope' and 'spectral Centre of Gravity' have been shown to be more reliable measures than average intensity measures (van Son & van Santen 2005, Sluijter, van Heuven & Pacilly 1997). Here, we calculated the spectral Centre of Gravity (CoG), which can be taken to represent 'both the relative produced power and the perceived loudness' (van Son & van Santen 2005: 105). Specifically, the CoG as a measure gives the frequency at which the spectral energy for a given range of frequencies is balanced. Like most other energy and intensity measurements it is sensitive to intrinsic vowel differences in being relatively low for back vowels such as /u/ (its low formants resulting in a low CoG) and being relatively high for front vowels like /i/ (with high F2 and F3 resulting in a higher CoG). The CoG was calculated at the midpoint of the steady-state portion of the vowel from the spectrogram (25 ms Gaussian window, up to 5000 Hz, timestep 50 ms).

Finally, vowel quality was measured by F1 and F2 values taken at the midpoint of the steady-state portion of the target vowel (which corresponded to the midpoint of the vowel with the exception of the syllables si and su which were characterised by considerable formant transitions in the stressed condition, see results). Measurements were extracted by means of the 'Burg' method in Praat (standard settings with timestep 10 ms). All values were verified manually, corrected where needed, or excluded where reliable formant values could not be extracted. Results are reported both on the raw F1 and F2 values and on Lobanov-normalised values. The latter were calculated with the *Norm* vowel normalisation suite (Thomas & Kendall 2007) and the R package *vowels* (Kendall & Thomas 2014).

3.4.2. Statistics

Statistical analysis was performed in R (R Core Team 2016) with linear mixed-effects regression models with the package *lme4* (Bates et al. 2015). Models with a very similar structure were run for each of the acoustic parameters under investigation. These always included presumed STRESS status (yes/no) as a fixed effect which interacted with GROUP (monolingual/bilingual) to investigate the possibility that monolinguals and bilinguals produce different acoustic enhancement patterns. Since pausing can be expected to have an effect on duration and f0, a third, non-interacting fixed effect of PAUSE (yes/no) was included for those two parameters. Models for f0 and spectral CoG moreover included DURATION (of the target vowel) as a covariate, to take into account that longer vowel length might contribute to more extreme values for other acoustic properties. To allow for speaker- and item-specific variation, random intercepts for SYLLABLE and SPEAKER were included in all models, excepting those for CoG and vowel quality. For these, SYLLABLE was entered as a main effect interacting with STRESS as the effect of stress can be expected to differ for different combinations of F1 and F2 (and CoG by extension). Thus, as two examples, the model for f0 had the structure STRESS GROUP + PAUSE + DURATION + (1|SPEAKER) + (1|SYLLABLE), whereas the model for CoG had the structure STRESS GROUP + SYLLABLE + STRESS:SYLLABLE + PAUSE + DURATION + (1|SPEAKER). statistical significance was calculated by means of likelihood ratio tests (LRTs) comparing main models with corresponding null models that lacked the relevant fixed effect or interaction term. When there was no significant interaction, the interaction term was dropped (this was only the case for the GROUP:STRESS interaction, with almost all results giving no reason to assume bilinguals behaved different from monolinguals). Multiple comparisons in the case of complex interactions (CoG and vowel quality) are performed using the Tukey method with the package *lsmeans* (Lenth 2016).

4. Results

4.1. F0

In this section we will first report on the global f0 contours characterising the utterances in which target words were embedded. After this we will consider static scaling properties of the f0 contours in terms of mean values in target vowels.

Figure 2 shows the time-normalised mean contours for all utterances in which target words were not surrounded by any pauses (N = 221, as described above). Contours on the target words do not differ much in overall shape, suggesting that there is little if any effect of stress on the f0 characteristics of target words. This is to be expected under the assumption that the words in this dataset should not be subject to postlexical prominence marking.

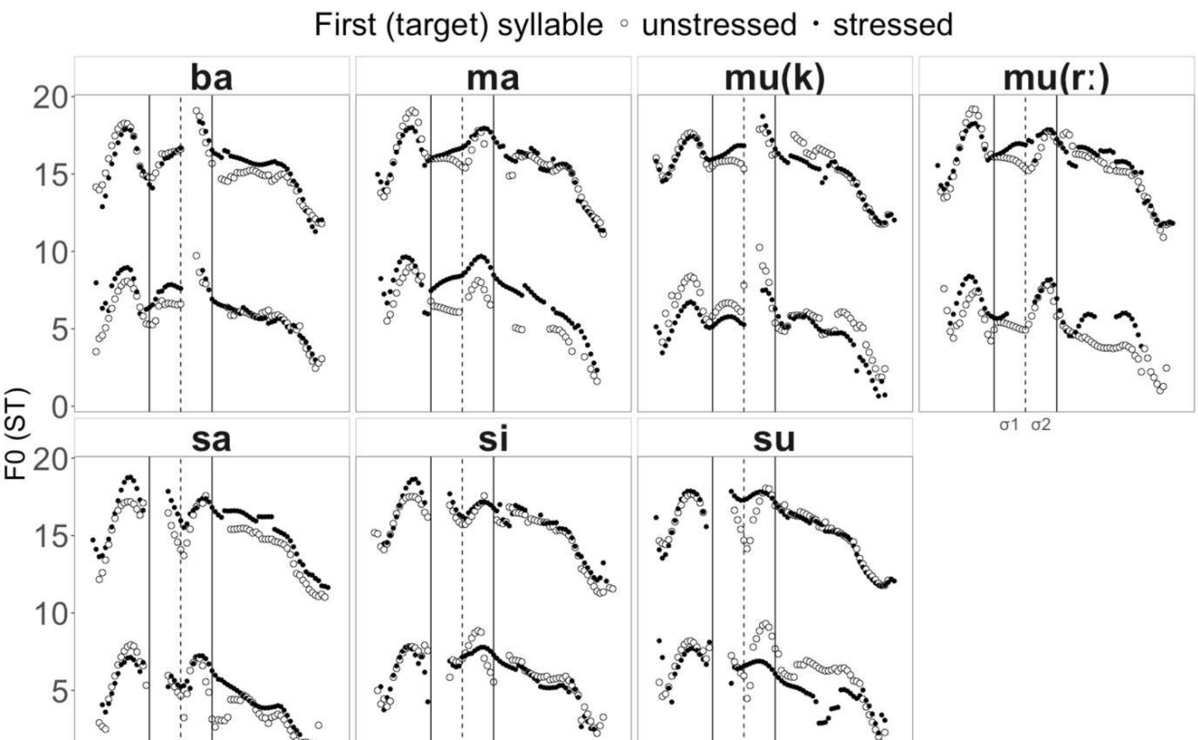

Figure 2 Phrasal intonation contours (averaged and normalised for duration) across N = 221 target utterances without pauses, male (bottom) and female (top) contours separated. Syllables of target words (σ 1: target syllable) indicated by vertical lines.

It can also be observed that all target words, irrespective of stress status, exhibit a small rise on the second syllable, near the right word edge. This is probably best interpreted as an edge-marking tonal event rather than a prominence-marking event, given their occurrence in a context where the target words are both postfocal and given. Crucially, though, the presence of a marginal pitch movement, which is consistent in location and does not map onto presumed stress status, highlights the difficulty in obtaining pitch-neutral stimuli despite careful experimental design. In the present experiment target syllables are found in word-initial position and thus do not themselves carry this rise. It would have been problematic, however, if presumed stressed syllables had occurred in word-final position, in which case there would have been a confound between positional and stress-related f0 characteristics. Such a scenario might have been the case in Boudlal's (2001) experiment. As mentioned previously, Boudlal proposes that stress targets the final syllable in cases where a word is produced in isolation. Words in isolation in his study were characterised by high pitch on the final syllable, most likely due to list intonation. Therefore, what Boudlal (2001) considers a pitch correlate of 'stress' rather seems to reflect a positional effect, and not necessarily a correlate of stress proper.

Having established that in the present case, target syllables are comparable in terms of their pitch properties, we now turn to more localised measures, applied to the full set of target words of N = 317. Firstly, there was no main effect of PAUSE on mean absolute f0 (as measured in semitones (ST)) (LRT χ^2 (1) = 0.86, p = .35; β = −0.1964, SE = 0.21, t = −0.93). There was, however an interaction between GROUP and STRESS (LRT χ^2 (1) = 6.07, p = .013; β = −0.56, SE = 0.23, t = −2.5). This meant that the bilingual group produced a slightly larger difference in pitch as a function of stress (stressed vowels had 1.1 ST higher pitch than unstressed vowels), than monolinguals (0.5 ST). There is therefore a general effect of STRESS with presumed stressed vowels having overall higher pitch than unstressed vowels. The size of these predicted differences however suggests that an attempt at a further explanation might be superfluous. Predicted differences of the above-mentioned magnitude are unlikely to translate into a robust perceptual cue to stress, as differences of 1 ST have been reported to be an absolute minimum in order for listeners to distinguish dynamic pitch movements (for example, exceptionally good listeners in 't Hart 1981, but see 't Hart 1976, d'Alessandro & Mertens 1995 for the suggestion that greater differences are required). Of course, perceptual retrievability is not a prerequisite for something to be a robust correlate of stress, but it does cast doubt on whether this correlate would be able to play a role in determining native speakers' judgment of stress at all. In short, the f0 results are more or less as expected, with no strong evidence in favour of the interpretation that presumed stressed syllables are enhanced in terms of f0. There was only a small, potentially negligible effect.

4.2. Duration

The total number of target words analysed for duration was the full dataset of N = 317 tokens, as mentioned above. Firstly, there was no main effect of PAUSE on any of the measures (for absolute vowel duration: LRT χ^2 (3) = 4.68, p = .20; β = 0.007, SE = 0.07, t = 0.11). The STRESS/GROUP interaction was significant only for z-scored syllable duration (LRT χ^2 (1) = 4.46, p = .03; β = −0.0091, SE = 0.005, t = −1.77). Since none of the other three duration measures (absolute syllable duration, and absolute/z-scored vowel duration) were significant this effect will not be further considered. There was, however, a main effect of STRESS on vowel duration (z-scored and absolute), although the predicted difference involves 'stressed' vowels being 3 ms SHORTER than 'unstressed' ones (LRT χ^2 (1) = 4.70, p = .03; β = −0.003, SE = 0.0017, t = −2.18). This change is not in the expected direction, but more importantly a change of 3 ms on an average vowel duration of around 77 ms does not reflect a meaningful change.

Figure 3 shows the distribution of absolute vowel duration, for each syllable separately and pooled across the groups. It does appear that differences exist between stressed and unstressed tokens of the syllables *si* and *su*. An explanation for this observation might be found in the segmental make-up of the word pairs involved. In the target words in which these syllables are stressed (*sira* and *sura*), there is a high vowel followed by [r] or [rˤ]. The rhotic considerably affected the preceding vowel formant structure and resulted in longer duration than in the unstressed counterparts *sinat* and *sudan*, which had steady-state only initial vowels (note that the other target syllables followed by /r/, i.e. *mu* and *ma* in murra [mərːa] and marra [mərˤːa], respectively, are much shorter, but the target vowel in these cases is central rather than high). Pre-/r/ lengthening of high vowels preceding rhotics is also observed in other languages, including Dutch (Rietveld, Kerkhoff & Gussenhoven 2004).

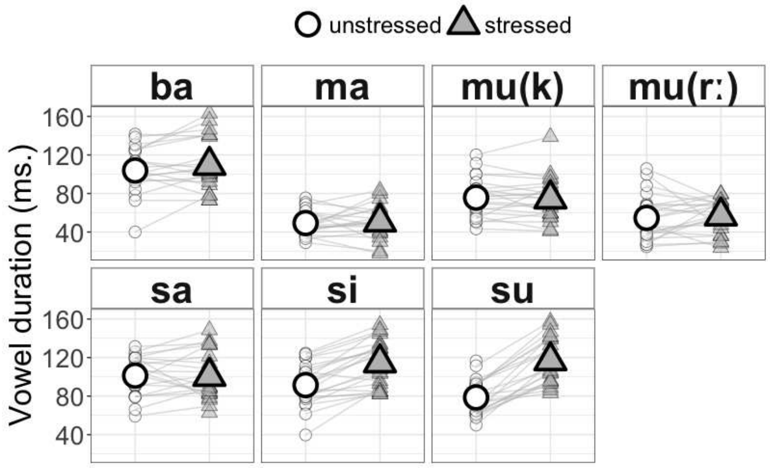

Figure 3 Duration of vowels as a function of presumed stress status. Lines link productions by the same speaker, large dots and triangles represent means.

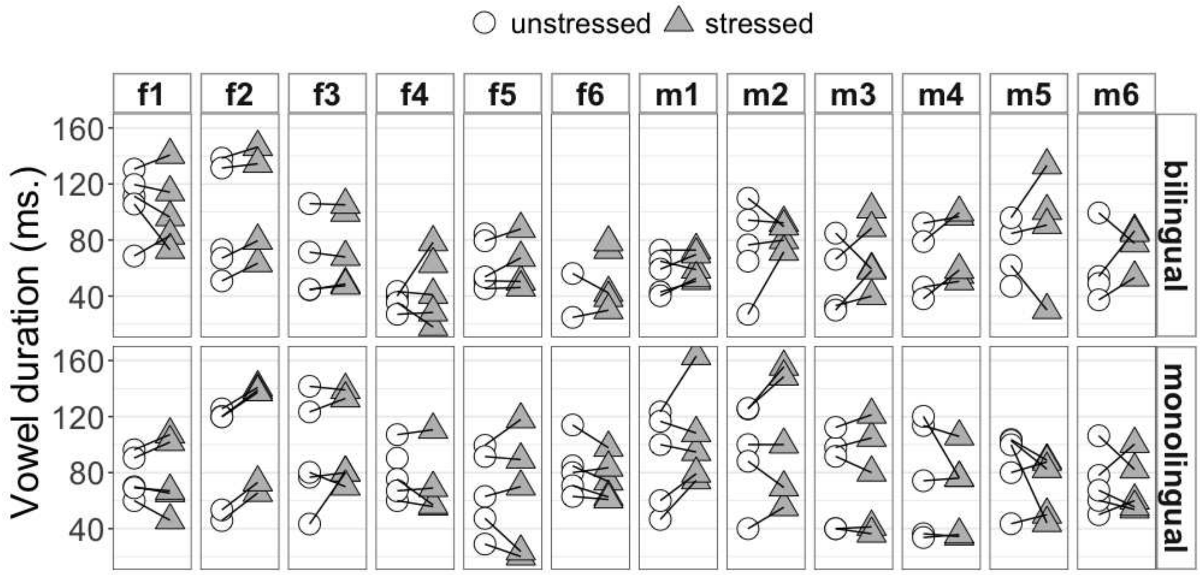

Figure 4 Duration of vowels in matched pairs of stressed/unstressed syllables, per speaker, tokens of *si* and *su* excluded.

In short, both statistics and the above observations suggest that there is no evidence to support an interpretation in terms of stress-induced vowel or syllable lengthening in MA across the board. To confirm that there are also no individual speakers who produce consistent durational enhancement of stressed vowels, Figure 4 shows speaker-specific behaviour (tokens of *si* and *su* are removed). Unstressed and stressed tokens of the same syllable are connected by lines (e.g. unstressed *mu* in *mukat* and stressed *mu* in *muka*). The varying direction of these lines for almost all speakers, and the large overlap between the presumed stressed and unstressed categories within each speaker, indicates that speakers did not systematically differentiate between stressed and unstressed vowels in terms of duration.

4.3. Spectral Centre of Gravity

The mean spectral Centre of Gravity for all items is shown in Figure 5, with matched pairs of vowels (productions by the same speaker) connected by lines (N = 309, four outliers with values above 1000 Hz were removed, and four could not be determined).

Firstly, there was no interaction between STRESS and GROUP (LRT χ^2 (1) = 0.73, p = .39; β = −17.73, SE = 20.79, t = −0.85), indicating that we did not find any production differences between monolingual and bilingual speakers. There was however, as expected, an interaction between STRESS and SYLLABLE (LRT χ^2 (6) = 18.253, p = .006), meaning that the effect of stress status was significantly different for the different vowel pairs. Posthoc multiple comparisons on this interaction revealed that the only significant differences as a function of STRESS occur with the syllables *si* and *su*, whose 'stressed' CoGs are higher than their 'unstressed' counterparts by an estimated 112 Hz (SE = 28.86, df = 293.09, t = 3.87, p = .0001) and 120 Hz (SE = 27.18, df = 284.35, t = 4.41, p < .0001), respectively. These are considerable differences, but might be in part explained by appealing to vowel quality differences which in turn might be the result of coarticulation and/or pharyngealisation (the sound following the 'stressed' vowels was a rhotic in both cases, see also Table 1). We will return to this finding in the next section on vowel quality.

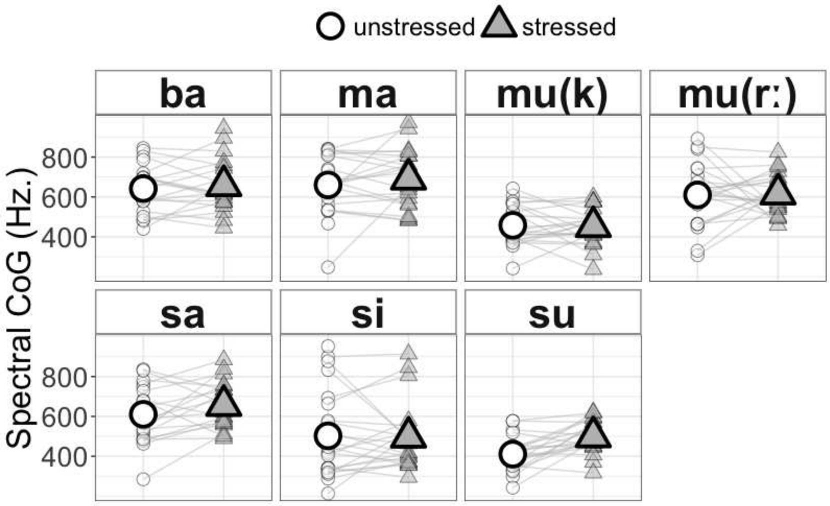

Figure 5 Spectral Centre of Gravity (absolute values) as a function of presumed stress status. Lines link productions by the same speaker, large dots and triangles represent means.

In sum, for five out of seven syllable pairs tested here there was no evidence that either speaker group or presumed stress status had any effect on the distribution of the spectral Centre of Gravity.

4.4. Vowel quality

Vowel quality was measured by F1 and F2. For N = 14 items the formants could not be determined, so that analysis was performed on N = 303. Given the aforementioned observations about formant transitions preceding the rhotic in target words *sira* and *sura*, formant measurements for these particular words are reported for the midpoint of the initial, steady-state part of the vowel.

As for the CoG, if there is an effect of presumed stress status, it is expected to affect different vowels differently, in the sense that stress might result in more extreme realisation in a relevant articulatory dimension (fronting for /i/ as opposed to backing for /u/, for example). In the following, results are shown for Lobanov-normalised values. Firstly, matching previous results, there was no interaction between STRESS and GROUP, for neither F1 nor F2 (F1: LRT χ^2 (1) = 0.06, p = .8; β = −0.03, SE = 0.10, t = −0.25, and F2: LRT χ^2 (1) = 1.66, p = .20; β = 0.06, SE = 0.05, t = 1.29).

Moving on to the effect of stress on individual vowel pairs, Figure 6 shows the stressed and unstressed vowels within a Lobanov-normalised vowel space. A first observation is that stressed vowels are generally not realised in the more extreme regions of the vowel space. There is a high degree of overlap in the distribution of most of the matched pairs of stressed/unstressed vowels: (i) *sada~sadat*, (ii) *baſar~baſart*, (iii) *marra~marrart*, and (iv) *muka~mukat*. The only clear differences between matched vowels occur in the syllables si and su, but those differences do not reflect hyperarticulation under stress. Stressed *si* appears to be less fronted than its unstressed counterpart, and stressed *su* appears to be less high. The differences within both vowel pairs are confirmed statistically by posthoc multiple comparisons: stressed *si* has a lower F2 when stressed (β = −0.56, SE = 0.07, df = 295.37, t = −8.42, p < .0001), while *su* has both higher F1 when stressed (β = 1.07, SE = 0.14, df = 303, t = 7.90, p < .0001) and lower F2 (β = −0.49, SE = 0.07, df = 280.67, t = −7.33, p < .0001). While an effort was made to measure vowel quality in the steady-state portion of the vowel, which presumably is less prone to anticipatory coarticulation with the following rhotic than the exact midpoint, it is likely that the attested differences are the result of differing neighbouring segments rather than stress per se. We will return to this finding below.

A second observation concerns the overlap in the distribution of vowels in *murra~murrin* and *marra~marrart*. We impressionistically transcribed both these vowels as [ə] in Table 1. The attested overlap in the vowel space confirms this similarity, despite the presence of vowel diacritics in the Arabic stimuli that should have made the distinction clear.

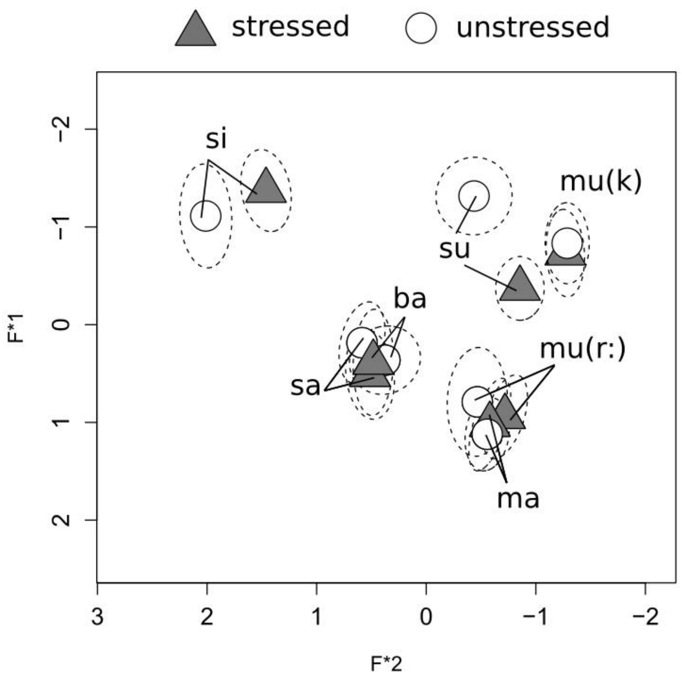

Figure 6 Mean formant values (Lobanov-normalised) for N = 303 target vowels, ellipses indicate 1 SD.

There were two remaining statistical differences: F2 was different between *murra* and *murrin* (lower F2 when the syllable is stressed, $\beta = -0.25$, SE = 0.06, df = 277.43, $t = -3.91$, $p < .0001$). We have no meaningful explanation for this effect and given its small magnitude (see overall distributional overlap in Figure 6) we will not discuss it further. A final observation concerns the differences between stressed and unstressed *sa*, with stressed *sa* having higher F1 ($\beta = 0.33$, SE = 0.13, df = 303, $t = 2.43$, $p = .02$).

In the following, we return to the significant differences that appeared to occur as a function of stress status and required some further explanation. Figure 7 presents an overview and a closer examination of the four vowel pairs that apparently differed as a function of stress: F1 differed for *si* and *sa*, F2 in *si*, *su* and *mu(r:)*. Judging from the individuals' patterns, the only consistent differentiation happens with stressed and unstressed vowels in *su* (*sura~sudan*). This, incidentally, is also a vowel pairing that involved a non-identical segmental environment, where *sura* was realised with both consonants pharyngealised. The effect on a vowel of a pharyngealised consonant in its vicinity is F1 raising and F2 lowering (e.g. Al-Tamimi 2017). This is exactly what is observed for the vowel in *sura* (stressed) compared to the vowel in *sudan* (unstressed). As was observed previously, *su* had a higher spectral CoG under stress, which can now be explained by its lower F1 under stress.

The differences in the other three syllables seem to be of a different kind. In *murra~murrin* and *sira~sinat* most of the effects seems to be carried by a small number of speakers (the few longer lines). For *sira~sinat* moreover the possibility of anticipatory coarticulation with the following rhotic in *sira* might be the cause of the 'stress' effect. Despite the posthoc significant difference, the vowels in the words *sada~sadat* exhibit a great deal of overlap, suggesting that no robust differentiation is made by most individual speakers.

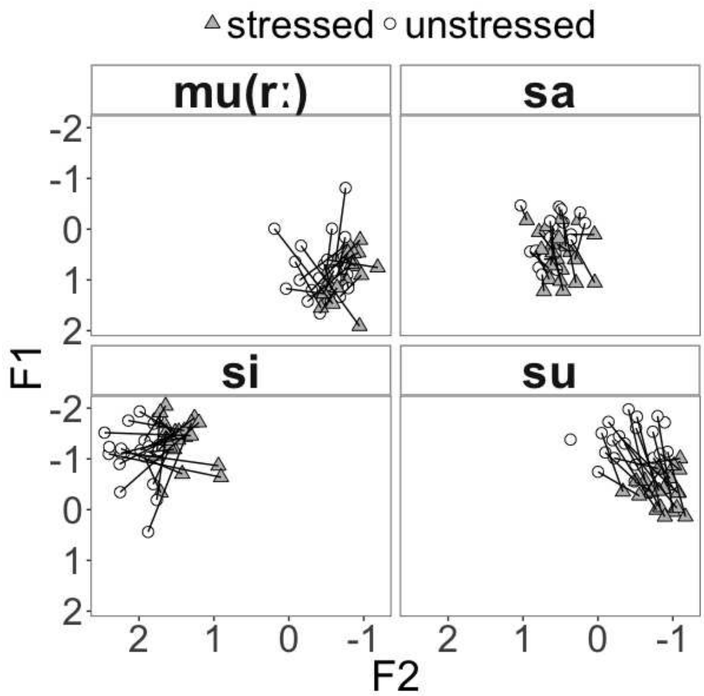

Figure 7 All individual tokens of target vowels for the four syllables *mu(r:)*, *sa*, *si* and *su* with lines linking individual speaker's stressed/unstressed renditions of the same vowel. Lobanov-normalised values.

Additionally, in *murra~murrin*, where stressed vowels are somewhat more peripheral, the 'stress' effect concerns a front/backness distinction, which might be explained away by coarticulation with the following vowel. The unstressed target vowel in *murrin* is followed by a high front vowel, while the stressed target vowel in *murra* is followed by a low vowel, so that in the former (stressed) case, we might have already expected to see some coarticulatory fronting.

In sum, for three out of seven syllable pairs there were no F1 and F2 differences between stressed and unstressed vowels. For the other four pairs, we argued that any apparent effects of stress on formant values could be explained by factors unrelated to stress, including pharyngealisation, coarticulation effects and/or speaker-specific behaviour. These results together do not provide evidence to support the hypothesis that vowel quality reliably distinguishes between 'stressed' and 'unstressed' positions, or indeed that individual speakers have 'stressed' and 'unstressed' realisational categories for vowels.

5. Discussion

For none of the acoustic correlates measured in this experiment (f0, duration, spectral CoG and vowel quality) were there convincing differences between presumed stressed and unstressed syllables, nor consistent patterns across speakers or speaker groups. No acoustic parameter was used consistently across syllable pairs to mark the distinction between stressed and unstressed syllables, and no syllable was consistently enhanced by multiple acoustic parameters. Additionally, in no case was there a meaningful difference between the speaker groups, which means this study provides no evidence that speakers who have Tashlhiyt as a first language in addition to Moroccan Arabic produce different lexical prominence patterns.

In order to conclude that stressed syllables stand out acoustically, there would have to be consistent differences across the board. A lexicon-wide effect in terms of acoustic enhancement of stress would require stressed syllable members to stand out from unstressed ones in most if not all words. In the present experiment, the only differences that were near-consistent were found for the syllables si and su, which appeared to have different duration and were subject to a CoG effect. Vowel quality in these syllable pairs was also different between stressed and unstressed members, but not in the expected direction (i.e. a more peripheral realisation under stress). The attested quality difference could be explained in terms of coarticulation rather than stress status, and it was argued that differences for other acoustic parameters are best interpreted as parasitic on this vowel difference.

Additionally, for the differentiation of stressed and unstressed syllables to be robust, individual speakers would be expected to systematically produce this distinction. In this experiment, different speakers did not make a consistent distinction: they did not use a combination of cues to enhance stressed syllables, nor did they consistently use any single cue (with the exception of those acoustic differences that could be explained in terms of an effect of neighbouring segments). This suggests that speakers do not produce two acoustically distinct categories 'stressed' and 'unstressed'.

While the present findings can thus not be considered to provide evidence in favour of the existence of (acoustic correlates of) lexical stress in MA, they also cannot simply be taken to provide evidence against it. On the one hand, this is a problem inherent to null results, as detailed earlier. A further complication is that even if MA has no lexical stress according to the rule tested here (stress the final syllable when it is heavy and the penultimate otherwise), lexical stress could still, potentially, be captured by appealing to another stress rule. In order to test different predictions, a different experimental setup would be needed. For example, when testing the claim that stress is final (e.g. Watson 2011), stimuli should contrast the same syllables in final and non-final positions. Although the present experiment was not designed to test for fixed final stress, the present data in fact allow for a quick comparison along these lines, contrasting the vowel /a/ in CV syllables in different positions, specifically in word-initial position in *sada*, versus in word-final position in *sada*, *muka*, and *sira*. If stress were consistently final, the vowel in *da*, *ka* and *ra* can be expected to be enhanced, or at least differentiated from initial *sa*. Figure 8 shows the distribution of measurements for /a/ in our dataset, comparing its spectral Centre of Gravity, duration, F1 and F2 in these syllables. This set (N = 51) excludes those syllables that were followed by pauses, to avoid the confound of phrasally induced lengthening effects that would likely result in disproportional enhancement of final syllables. Potential side-effects caused by different segmental make-up of the onset (even if not measured) cannot be excluded: /s/ is used in initial position where /d k r/ occur as onsets in final position. On the whole, however, given these very basic results, it does not appear that vowels in word-final position are systematically differentiated from vowels in initial position.

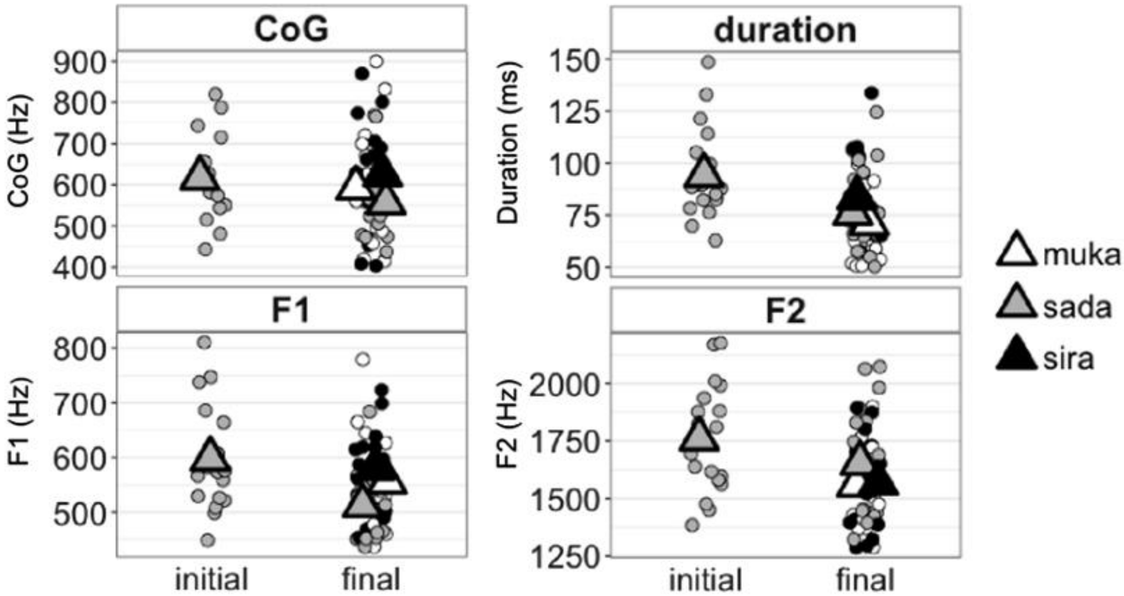

Figure 8 Spectral Centre of Gravity, duration, F1 and F2 values for /a/ in initial position (*sada*) compared to in final position (*muka*, *sada* and *sira*) across the all tokens produced without pausing (N = 51). Large triangles reflect means.

To return to the question of what, if any, stress generalisation might hold in MA, currently there is no concrete evidence from any diagnostic of stress (acoustic correlates, native speaker judgments, phonological rules, etc.) that support an interpretation in favour of MA having a stress-by-position system, or in fact in favour of any other interpretation of stress assignment.

Thus, the present null results are likely to accurately reflect a situation in which MA lacks lexical stress altogether. Such an interpretation is compatible with prior work, including the general lack of success in identifying the position of lexical stress, and the apparent absence of other exponents of stress in the language. Firstly, this lack of success in diagnosing stress concretely involves native speakers' varied judgments on stress position in MA and the century-long disagreement among scholars on the proper representation of stress. Both of these types of evidence highlight that the concept of stress in MA is an elusive notion, which is a strong indication that it might not play much of a role in the phonology of the language. Secondly, the apparent absence of other exponents of stress has to do with the intonational phonology of MA and the generally held assumption that stressed syllables serve as docking sites for postlexical pitch accents. As reviewed in Section 2.4.3, all experimental studies to date on the alignment of prominence-lending intonational events in MA suggested that similar movements in MA are either absent or difficult to characterise as pitch accents. A different argument to support an interpretation along the lines of the absence of lexical stress in MA comes from one of its contact languages, Tashlhiyt

Berber. This variety of Berber specifically is considered to lack lexical stress (see Section 2.2), although other, closely related varieties of Berber spoken in Morocco might also lack it (Kossmann 2012). It is well known that the segmental phonology of MA exhibits features that can be traced back to prolonged contact with Berber (e.g. Heath 1997, Dell & Elmedlaoui 2002, Maas & Procházka 2012; see also Zellou 2010). It is conceivable therefore that not only segmental phonological structure, but prominence structure too has been influenced by contact with the Berber languages, supporting the possibility that stress is absent in both Moroccan Arabic and Moroccan Berber.

In order to claim convincingly that Moroccan Arabic lacks lexical stress, in the sense of designating one syllable in each word as being marked by culminative prominence, further evidence will be needed. The absence of acoustic enhancement of presumed stressed syllables, as shown in the present experiment, is but one of several diagnostics that might serve to support the claim that stress is absent. Nevertheless, most if not all experimental evidence available to date is compatible with the absence of stress in MA.

6. Conclusion

The experiment reported in this paper investigated acoustic correlates of lexical stress in Moroccan Arabic by contrasting presumed stressed syllables with unstressed ones. According to the view tested, the penultimate syllable of a word is stressed, unless the final syllable is heavy, in which case stress is final (Benkirane 1998, Boudlal 2001).

The results from the present experiment could not provide evidence in favour of acoustic enhancement of ‘stressed’ syllables according to this rule. Acoustic properties of stressed syllables – f0, duration, spectral Centre of Gravity or vowel quality – did not consistently or meaningfully differ from those found in unstressed counterparts. This lack of consistent enhancement was observed across the board. Specifically, effects were absent for most syllable comparisons (suggesting that the effect does not hold across the lexicon), and, where these could have been expected, systematic effects were also absent for individual speakers (suggesting that speakers do not produce categorical differences between stressed and unstressed syllables).

While these null findings do not provide conclusive evidence in favour of the absence of lexical stress in MA, they are very much compatible with it. The present results are also compatible with earlier claims and experimental results suggesting that lexical stress does not play a large role, if any, in the phonology of the language.

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