Syllable Weight: Phonetic Duration and Phonemic Contrast*

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This paper addresses two questions: why, in quantity-sensitive systems, do CVV and CVC syllables constitute better stress targets than CV syllables, and why does the weight of CVC syllables vary? I argue that CVV syllables are optimal stress targets because their long vowel duration allows for the best expression of the phonetic correlates of stress. Although CVC syllables appear to attract stress in some languages, this attraction should be understood as a consequence of stress repulsion from CV syllables. The stress attraction of CVC syllables occurs only where CV syllables are subject to positional vowel lengthening and stress-induced lengthening. In this position, CV syllables repel stress to preserve the phonemic contrast of vowel length. CVC syllables are protected from extreme vowel lengthening in the same positions due to closed syllable shortening. I present experimental evidence from Jordanian Arabic where only CVV and CVC syllables attract stress in penultimate position, to support my claim that vowel lengthening effects in penultimate CV syllables are extreme. As a result, CV syllables avoid stress to maintain their phonemic vowel length and CVC and CVV syllables receive stress in the target position. I conclude that CVC syllables are not inherent stress attractors at all.

Key words: syllable weight, phonetic vowel duration, phonemic vowel length contrast, Jordanian Arabic

1. Introduction

The position of stress is sensitive to the distinction between heavy and light syllables in many languages. In such languages, stress primarily falls on heavy syllables, which are invariably CVV syllables and variably CVC

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syllables. The weight of CVC syllables varies depending on the language as well as the phonological context (Hayes, 1989; 1994; 1995). In other words, if stress falls on CVV syllables over CVC and CV syllables as in Khalkha (Hayes, 1981), then only CVV syllables count as heavy. If stress falls on CVV and CVC syllables over CV syllables as in Latin (Steriade, 1988), then both CVV and CVC syllables count as heavy. This phonological account does not go beyond the statement that stress is attracted to heavy syllables. It does not account for why CVV syllables, and sometimes CVC syllables, but never CV syllables are primary stress attractors in so-called quantity-sensitive languages.

This paper attempts to provide a phonetic and functional account for the behaviors of heavy CVV, heavy/light CVC, and light CV syllables in primary stress patterns. Based on the perspective that cross-linguistic stress patterns can be classified by the phonetic properties of stress, this paper investigates the relationship between vowel duration and syllable weight. I claim that vowel duration is the crucial determinant for stress targets. CVV syllables are optimal targets for stress because their intrinsic long vowel duration allows for the best expression of the three phonetic properties of stress: pitch change, increased vowel duration, and increased intensity (Lehiste, 1970). In contrast, CVC syllables do not display long vowel duration, and are not therefore, optimal stress targets. I argue that the attraction of stress to CVC syllables is only apparent, and should instead be understood as a consequence of stress repulsion from CV syllables. CVC syllables appear to attract stress only in positions in which stressed short open vowels undergo extreme lengthening enough to jeopardize the phonemic contrast of vowel length. For example, in languages lacking phonemic vowel length such as Tagalog (French, 1988), Cebuano (Bunye & Yap, 1971), Ilokano (Hayes & Abad, 1989), the extreme vowel lengthening of stressed CV syllables in penultimate position has been well known.

This paper presents experimental evidence from Jordanian Arabic in support of the hypothesis that CV syllables avoid stress to maintain phonemic vowel length in certain positions, so that CVV and CVC syllables appear to pattern together as heavy syllables. Stress in Jordanian Arabic preferentially falls on heavy CVV and CVC syllables over CV syllables in the penultimate position. The experiment shows that CV syllables, unlike other syllables, undergo an extreme vowel lengthening under stress in the penultimate position, which would give rise to

possible neutralization phonemic contrast of vowel length. First, section 2 presents 5 independent observations on the restricted distributions of CVC heavy syllables, stress-induced lengthening, positional lengthening and closed syllable shortening, which lead to the proposal of this paper. Section 3 briefly discusses why vowel duration is crucial for stress assignment. Section 4 presents experimental evidence from Jordanian Arabic. The experiment demonstrates that three factors (stress, position, and openness of a syllable) clearly have vowel lengthening effects in Jordanian Arabic and these effects are accumulative in stressed open penultimate syllables so that the phonemic contrast of vowel length between unstressed CVV syllables and stressed CV syllables have a chance to be neutralized. Section 5 investigates why CVC syllables in the final position in JA do not bear stress.

2. Observations and Proposal

In this paper, I claim that CV syllables in or near word-edge positions tend to avoid stress in order to maintain phonemic contrast with CVV syllables since CV syllables tend to undergo extreme vowel lengthening in those positions under stress. This claim is based on 5 independent observations. First, stress makes a vowel lengthen regardless of its intrinsic duration (Parmenter & Trevino, 1935): In English an average stressed vowel is approximately 50% longer than an average unstressed vowel. Czech, Finnish and Estonian (Lehiste, 1970) have the same patters.[1)]

Second, many studies (Oller, 1973; Klatt, 1975; Beckman & Pierrehumbert, 1986; Crystal & House, 1990; Wightman et al., 1992) demonstrate that there is vowel lengthening in word-final or phrasal-final positions cross-linguistically, regardless of the size of words or phrases and regardless of stress. For example, Spanish and Japanese (Hoequist, 1983) show a tendency to lengthen syllables towards the right-end of a word: final syllables tend to be longer than medial, and medial syllables tend to be longer than initial syllables. There are other kinds of positional lengthening, which seem to be sensitive to the stress position for the majority

1) Van Heuven and Sluijter (1996, p. 246) state that the accented syllable is not stretched linearly; rather, the middle portion of the vocalic nucleus is stretched more, with the effect tapering off towards the consonantal edges.

of words in a language. Tarnoczy (1965) reports that Hungarian, whose main stress falls on initial syllables, has a lengthening effect toward both edges of a word: medial syllables tend to be the shortest. Kirchner (1997) proposes two universal constraints: Word-Initial Lengthening and Phrase-Final Lengthening, arguing that word-initial and phrase-final vowel lengthening are cross-linguistically common phenomena and these partial lengthening effects are responsible for the restricted vowel centralization of Nawuri, a Kwa language of Ghana, where short non-back vowels are centralized except in word-initial or phrase-final position. Languages which have predominantly penultimate stress tend to lengthen penultimate vowels. A stressed open syllable in penultimate position is significantly longer than a stressed open syllable in other positions in Chamorro (Chung, 1983), Cebuano (Shryock, 1993) and Italian (D'imperio & Rosenthall, 1999). It seems that word-final lengthening is cross-linguistically common, while word-initial and penultimate lengthening depend on the stress patterns of a language.

Third, vowels in a closed syllable are shorter than vowels in an open syllables (Maddieson, 1984). Maddieson (1984) reports that vowels are shorter in closed syllables than in open syllables in Dutch (Rietveld and Frauenfelder, 1987), English and Russian (Jones, 1950), Finnish (Wiik, 1965), Korean (Han, 1964), and Thai (Abramson, 1962).

Fourth, CVC syllables count as heavy in languages with phonemic vowel length (De Chene & Anderson, 1979). As far as primary stress is concerned, the observation does hold (Ahn, 1999).[2] Ahn's survey on primary stress patterns confirms that CVC syllables count as heavy in languages with CVV syllables.[3] According to the survey, in quantity-sensitive languages lacking long vowels, CVC syllables do not function as heavy, rather syllables with low, non-high or full vowels function as

2) The survey does not cover secondary stress, but only primary stress. It has been already noted that syllable weight within a language may vary depending on the process (Hayes, 1995; Gordon, 1999). The author has the position that syllable weight should be defined within the phonological process, based on its own characteristics and functions. Along this line, primary stress may differ from secondary stress in defining syllable weight since they differ in their function. Primary stress has culminative and demarcative function, while secondary stress has rhythmic function. The independence of primary and secondary stress in stress algorithm has also been discussed in Van der Hulst (1999).

3) CVC syllables in both English and Spanish appear to count as heavy without phonemic long vowels. These apparent counter-examples arise from the loss of vowel length historically. Therefore, it should be that CVC sylalbles count as heavy only in languages with phonemic vowel length, *synchronically* or *historically*.

heavy. Why can't CVC syllables function as heavy without CVV syllables?[4)]

Fifth, Ahn's survey on quantity-sensitive stress systems revealed that as main stress attractors, CVC syllables count as heavy in restricted positions: initial, penultimate, and final positions of a word, while CVV syllables count as heavy in any positions. When a language locates stress in a rightmost or leftmost heavy syllable, which can occur in any position of a word, the heavy syllable refers only to long voweled syllables, not CVC syllables. CVC syllables function as heavy only in bounded quantity-sensitive stress systems, where stress primarily occurs in intial, penult, and final position within a word.[5)] It is notable that these 3 positions are exactly the same positions reported to show positional lengthening effect.

Pulling 5 observations together, we can expect two different patterns depending on the vowel system of a language when stress falls near or on the word edges with positional lengthening effect. First, in a language lacking phonemic vowel length, stress would realize on a target position (e.g., penultimate position) no matter what the target syllable is. Stressed CV syllables would have an extreme long vowel duration by accumulative effects of positional lengthening and stress-induced lengthening, as shown in (1a). On the other hand, stressed CVC syllables would be protected from this extreme lengthening in the same position, due to the closed syllable shortening, in (1b).

(1) Language without CVV syllables
  a. CV.CV.ˈCV.CV#
        [CV:]
  b. CV.CV.ˈCVC.CV#

4) This observation suggests that CVC syllables may not have stress attracting properties by themselves.

5) Ahn's survey (1999) reports that the primary stress targets in both QI and bounded QS systems are the same three positions (word-initial, -penultimate, and -antepenultimate positions). In bounded QS systems, stress may occur in second or antepenultimate position of a word. However, it is important to note that those positions are not the primary stress targets. For example, the stress pattern of Latin is the following: stress in Latin falls on the penultimate syllable when the syllable is heavy; or the stress falls on the antepenultimate syllable. Here, we see that the antepenultimate position is stressed by default. In other words, the primary stress targets in both QI and bounded QS systems are the three positions, but not so-called heavy syllables. Two systems differ only in that stress in bounded QS systems may shift to other adjacent positions due to the weight of syllable in the target position (or in the adjacent syllable).

This predicted pattern occurs in languages such as Chamorro (Chung, 1983), Cebuano (Shryock, 1993) and Italian (D'imperio & Rosenthall, 1999). In those languages, stressed penultimate CV syllables show extreme long vowel duration, compared to stressed penultimate CVC syllables or stressed syllables in other positions.

Second, stress in a language with phonemic vowel length would avoid falling on CV syllables in order to maintain phonemic contrast of vowel length. Otherwise, stressed CV syllables would undergo extreme lengthening by position, openness of a syllable and stress, which leads to neutralize phonemic vowel length. Instead, stress falls on a position where there is no or less positional lengthening effect, as in (2). Thus, in the first target position, only CVV and CVC syllables would receive stress.

(2) Language with phonemic vowel length
a. CV.CV.ˈCVV.CV#
b. CV.CV.ˈCVC.CV#
c. CV.ˈCV.CV.CV#
←[CV:]

This pattern appears in Latin and Arabic, where stress falls on heavy penultimate CVC and CVV syllables or on antepenultimate syllables.

Diagram (3) shows predicted schematic vowel durations of stressed and unstressed CVV, CVC, and CV syllables in penultimate and antepenultimate positions in a language which has stress in the penultimate position, and which is assumed to have stress-induced lengthening, penultimate lengthening, and closed syllable shortening (open syllable lengthening) effects. It is also assumed that the lengthening effects of these three lengthening phenomena are cumulative. In (3), VV, V, O, P, and S stand for long vowel duration, short vowel duration, open syllable lengthening (closed syllable shortening), penultimate lengthening, and stress-induced lengthening respectively.

(3) Schematic vowel durations

a. Stressed CVV in Penult

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|-------------------------------------------|----|----|----|
                VV                          O    P    S
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b. Unstressed CVV in Penult

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|-------------------------------------------|----|----|
                VV                          O    P
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c. Unstressed CVV in AnteP

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|-------------------------------------------|----|
                VV                          O
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d. Stressed CV in Penult

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|-------------------------|----|----|----|
                V      O    P    S
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e. Stressed CVC in Penult

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|-------------------------|----|----|
                V      P    S
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The diagram shows that stressed CVV syllables (3a) undergo the same extreme vowel lengthening as do stressed CV syllables (3d). It also shows that the vowel duration of stressed penultimate CV syllables in (3d) almost reaches the vowel duration of unstressed antepenultimate CVV syllables in (3c) because the former undergo greater lengthening due to both positional and stress-induced lengthening. Given that vowel duration is a major cue for the contrast between long and short vowels, such a small difference in duration between unstressed long vowels and stressed short vowels is not desirable even though it is true that phonemic vowel length is realized differently depending on the position. Therefore, under such an extreme vowel lengthening condition, the phonemic contrast of vowel length between unstressed long vowels and stressed short vowels would be neutralized.

Indeed, psychoacoustic experimentation reports that the contrast of phonemic vowel length is observed only in stressed positions and is neutralized in unstressed positions (Koopmans-van Beinum, 1980). It has also been reported that in some languages with phonemic vowel length and a quantity-insensitive stress system, the vowel length contrast is neutralized in unstressed positions. Kerek (1968) reports that in Hungarian, the objectively measured duration of short stressed vowels often equals the duration of unstressed long vowels. Potisuk et al. (1996) report that

the contrast of vowel length in Thai is neutralized in unstressed syllables. Elbert (1964) adds that the durational differences between long and short vowels in Swedish are weakened or neutralized in unstressed positions.[6]

In sum, I claim that the apparent stress attracting behavior of CVC syllables in or near word-edge positions is a consequence of stress avoidance of CV syllables in the same position for the maintenance of phonemic contrast of vowel length.

3. Syllable Weight and Phonetic Manifestation of Stress

In QS stress systems, CVV syllables invariably count as heavy, while CVC syllables variably count as heavy. I have claimed that the stress attracting properties of CVC syllables should be understood as a consequence of stress repulsion from CV syllables and CVC syllables are not inherent stress attractors at all. On the other hand, CVV syllables function as heavy in any position of a word, unlike CVC syllables. For example, in Khalkha, stress primarily falls on the rightmost long voweled syllable no matter where the long vowel is positioned within a word. I claim that CVV syllables are truly inherent stress attractors due to their long vowel duration, which can manifest phonetic properties of stress best.

Stress is phonetically manifested by increased duration, increased amplitude, and pitch change (Lehiste, 1970). Among sounds, vowels are the most optimal stress targets since they have high amplitude and rich harmonic structures which can manifest pitch contour the best (Beckman 1986). Especially long vowels are preferred to short vowels as stress targets. The intrinsic long duration of long vowels is consistent with stress-induced vowel lengthening. The long duration makes a sound perceptually louder, and the longer vowel duration provides more time

6) However, not all languages with phonemic vowel length show stress repulsion of CV syllables in the stress target position, or phonemic neutralization of vowel length. It is because various phonetic vowel lengthening effects may vary in degree from language to language. For example, Kekchi (Berinstein, 1979) has a phonemic long vowel and locates stress on the final syllable without phonemic neutralization of vowel length, or stress repulsion of CV syllables. Berinstein (1979) finds that stress in Kekchi is not manifested by increased vowel duration, and therefore, the extreme vowel lengthening of stressed CV syllables is not expected in Kekchi. As a consequence, neither phonemic neutralization of vowel length nor stress repulsion of CV syllables are expected in Kekchi.

for the realization of a full pitch contour. Lian and Chistovich (1960) and Henning (1970) show that shorter vowels require larger fundamental frequencey difference to be perceived as different in pitch. Similarly, Nabelek et al. (1970) present that the pitch change is identified as a single frequency if the transition duration is short or the frequency excursion is small enough.

Along the line, I claim that in languages lacking long vowels, low vowels or full vowels are the better stress targets than non-low vowels or reduced vowels, since the former have longer duration than the latter. Other things being equal, a low vowel is longer than a high vowel, since low vowels involve larger articulatory movements from and to the surrounding consonantal constrictions (Lindblom, 1967; Klatt, 1976; Lehiste, 1976; Beckman, 1986). The relationship between vowel height and vowel duration has been tested for English (Black, 1949; Petersen & Lehiste, 1960; Umeda, 1975; Westbury & Keating, 1980; Van Santen & Olive 1990), for Standard Japanese (Han, 1961), for Kyoto Japanese (Homma, 1981), and for German, Swedish, Thai, Lappish, and Spanish (Lehiste, 1970).

In fact, some languages lacking vowel length contrast locate stress on a syllable with a full vowel, low, or non-high vowels primarily or on initial, penultimate or final syllable. Eastern Cheremis (Kiparsky, 1973; Hayes, 1981) locates stress on the rightmost syllable with a full vowel. If a word contains only reduced vowels, then the initial syllable is stressed.

4. Experiment

4.1. Purpose

The experiment was designed to test the claim that CV syllables in penultimate position avoid stress in order to maintain phonemic contrast since otherwise they would undergo extreme lengthening by stress, position and openness of the syllable. If the claim is to be true, a language with heavy CVV and CVC sylalbles in its stress system should show three phonetic vowel lengthening/shortening: stress-induced lengthening, closed syllable shortening, and positional lengthening, and also the accumulative effect of those three.

Jordanian Arabic was chosen as a target language since stress in Jordanian Arabic preferentially falls on heavy CVV and CVC syllables

over CV syllables.[7] Stress in Jordanian Arabic falls on final syllables if they are CVVC, CVV as shown in (4a). Otherwise, stress falls on penultimate syllables unless they are CV syllables as shown in (4b). When CV syllables occupy the penultimate position, stress goes to the antepenultimate position, where I predict there is no extreme vowel lengthening of stressed CV syllables.

(4) Stress in Jordanian Arabic (Alghazo, 1987)[8]

a. Stress the final if it is CVVC, or CVV syllable.[9]

dux'xaan	'smoke'
sa'laa	'prayer'

b. Stress the penult if it is heavy (CVV or CVC).

ʔa'malti	'you (f. sg.) did'
fa.'naa.dig	'hotels'

c. Otherwise, stress the antepenult.

'katabu	'he wrote'
ma'katabis	'he did not write'
'katbatu	"we named him'

This experiment focused mainly on the stress pattern in penultimate position, since the pattern has been argued to be solely related to syllable weight, not with extrametricality.

The experiment tested four hypotheses: i) Stressed vowels are longer than unstressed vowels. ii) Vowels in open syllables are longer than vowels in closed syllables. iii) Vowels in the penultimate position are longer than vowels in the antepenultimate position. iv) The lengthening effects are accumulative.

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7) Among dialects of Jordanian Arabic, northern dialect spoken in Ajloun mountain area was selected for the target language.

8) Alghazo (1987) who researched the same dialect described the stress pattern as the same as the stress pattern in Ammani-Jordanian and Palestinian Arabic which has no word ending with a long open vowel (van der Vijver, 1996). However, I found that words ending in a long open vowel such as *hayaa* ('life') and *salaa* ('a prayer') exist and the final long open vowels are stressed in this dialect.

9) Alghazo (1987) states that the final CVCC syllables are stressed (i.e. *da'rast* 'I studied'). In fact, I found that there are no consonant clusters in word final position, no CVCC due to the vowel epenthesis process. The word '*da'rast* ('I studied')' is pronounced as '*da'rasit*'.

4.2. Method

In order to test the given three hypotheses, the vowel duration of four different types of syllables (CVVC, CVV, CVC, CV) were measured in the final, penultimate and antepenultimate positions of tri-syllabic words under both stressed and unstressed conditions. The measurement was expected to show the effects on vowel duration of three factors: open/closedness of a syllable, position, and stress. Final position was included in order to measure the mean duration of long and short vowels and to investigate the stress pattern in the final position.

It is well known that vowel duration is influenced by various linguistic factors such as stress, the segmental quality, the voicedness of postvocalic consonants, the structure of syllables (open or closed), the word-size, the position within phonological units, besides accent of the speaker, the overall tempo and the current paralinguistic state of the speaker, well known in a variety of languages such as Danish, Dutch, German, Japanese and Italian, but mainly in English (Peterson & Lehiste, 1960; Fischer-Jørgensen, 1964; Lehiste, 1970; Nooteboom, 1972; Oller, 1973; Klatt, 1976; Homma, 1981; Kohler, 1986; Farnetani & Kori, 1986; Crystal & House, 1988).

In order only to test three phonetic factors - stress, position within a word, and closed/openness of a syllable - on vowel duration, the word list was constructed to include only words whose target vowel is a low vowel [a] since each vowel has its own intrinsic vowel duration.[10] Also, the target vowel precedes only voiced consonants in order to reduce the influence of postvocalic consonants on the vowel length.[11] The word-size was restricted into three syllables to avoid the effects from differences in word-size. Two words were selected for each category except the final stressed long voweled syllables (CVVC and CVV), each of which had one word selected for them. A frame sentence was constructed to minimize prosodic differences.

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10) See Appendix for the word list.

11) The word list simply disregarded the effects of the prevocalic consonant and the place of articulation and the manner of the postvocalic consonant, which have not been considered as significant factors on vowel duration. Lehiste (1970) and Umeda (1975) report that there is no consistent result on the effects of the place of articulation and the manner of the postvocalic consonant, and the effects of the prevocalic consonant.

(5) Frame Sentence: I saw _____ outside.
(ʃuft _____ barrạ)

The subjects were two female and one male native Jordanian Arabic speakers who were graduate students at age 22 to 27. They were presented with the word-list randomly ordered and the frame sentence written in English, and were asked to say each word within the frame sentence, translating the entire sentence into their language. The presentation of test items in English was designed to reduce the influence of orthography and to encourage the use of colloquial Arabic. Subjects were asked to speak the given sentences at the constant rate. The process was repeated five times.

4.3. Analysis Procedure

Speech was recorded and analyzed using the Entropics Waves software for digital speech analysis. The utterances were digitized at a 16KHz sampling rate. The duration of target vowels were measured manually from spectrograms, waveforms and amplitude color maps. The segmentation follows the following conventions (Olive et al., 1993; van Santen, 1992; Shoup & Pfeifer, 1976; Peterson & Lehiste, 1960): The first formant served as the vowel onset indicator when voiceless consonants preceded; the consonantal aspiration was not included in the vowel duration; the boundary between vowels and voiced consonants was determined by the abrupt cessation of formants (the abrupt change in amplitude); the boundary between liquid [l] and vowels was detected by a visible discontinuity or changes of the energy of the third formant. The transition from a nasal to a vowel was indicated by the location where the steady nasal formant changes into the on-glide movement of the onset of vowel. The transition from a vowel to a nasal was detected by sudden change in the formant structures.

4.4. Results

Table I shows the average duration of each category which is classified by 4 factors: stress, position, open/closedness, and vowel length.

Table 1. Average Vowel Durations which are Balanced by Stress, Position, and Syllable Structure.
(C and O indicate closed and open vowels respectively.)[12]

Position	Syllable Type	Stressed	Unstressed
Final	C (CVVC)	156 ms.	
	O (CVV)	173 ms.	
	C (CVC)		73 ms.
	O (CV)		81 ms.
Penult	C (CVVC)	128 ms.	
	O (CVV)	137 ms.	120 ms.
	C (CVC)	69 ms.	51 ms.
	O (CV)	80 ms.	65 ms.
AnteP	C (CVVC)		
	O (CVV)	127 ms.	108 ms.
	C (CVC)	57 ms.	46 ms.
	O (CV)	64 ms.	57 ms.

4.4.1. Stressed vs. Unstressed Vowels

In order to compare duration between stressed and unstressed vowels, vowel durations in 6 sets of stressed and unstressed CVV, CVC, and CV syllables in penultimate and antepenultimate positions are measured. Syllables in final position was exempt from this measurement since long voweled syllables occur as stressed and short voweled syllables as unstressed all the time. The final position does not have any pair of stressed and unstressed syllable. Stressed vowels in penultimate and antepenultimate CVV, CVC and CV syllables are 89 ms. and unstressed vowels in penultimate and antepenultimate CVV, CVC, and CV syllables are 75 ms. on average. The difference between two groups is 14 ms. The relative duration of stressed to unstressed vowels is 1.2:1. Stressed vowels are 20% longer than unstressed vowels.

ANOVA test confirms that the duration of stressed vowels is significantly different from the duration of unstressed vowels ($F(1,348)=137.2$, $p<0.001$).[13]

12) In Jordanian Arabic, stress can fall on penultimate CV syllables in di-syllabic words or tri-syllabic words with the initial unstressable definite article *il*.

13) Analysis of variance (ANOVA) is a statistical procedure used to evaluate the mean

4.4.2. Open vs. Closed syllables

Vowel durations of CV and CVC syllables were measured in stressed and unstressed final, penultimate, and antepenultimate positions. On average, CV syllables and CVC syllables are 69 ms. and 59 ms. respectively, and the actual difference in duration between them is 10 ms. The relative duration ratio of open vowels and closed vowels is 1.16 : 1. Open vowels are 16% longer than closed vowels, if other things are equal.

The difference between open and closed vowels in duration is statistically significant ($F(1,348)=74.7$, $p<0.001$).

4.4.3. Penultimate vs. Antepenultimate Vowels

In order to compare duration between penultimate and antepenultimate vowels, vowel duration of stressed and unstressed CVV, CVC and CV syllables in both positions were measured. Penultimate and antepenultimate vowels are respectively 87 ms. and 77 ms. on average. Between penultimate and antepenultimate vowels, the difference in duration is 10 ms. and the duration ratio is 1.13 : 1. Penultimate vowels are 13% longer than antepenultimate vowels.

ANOVA test shows that the mean durations of penultimate vowels and antepenultimate vowels are significantly different at $F(1,348)=65.7$, $P<0.001$). Other things being equal, penultimate vowels are longer than antepenultimate vowels.

4.4.4. Accumulative Effects of Phonetic Lengthening and Shortening

First, the experiment shows that long vowels are about twice as long as short vowels in Jordanian Arabic. The durations of both long vowels and short vowels were averaged in all three positions, regardless of whether they are closed or open and whether they are stressed or unstressed. Long vowels are 136 ms. and short vowels are 64 ms. on average. The difference between the two groups is 73 ms in duration, and the duration ratio is 2.1 : 1.

Next, in order to show the accumulative effect of stress-induced lengthening, closed syllable shortening, and positional lengthening (penultimate lengthening), I represent vowel duration of each syllable in both penultimate and antepenultimate positions in Figure 1.

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difference between two or more groups. It differs from *t-test* since more than two groups are tested, simultaneously.

Figure 1. Vowel Duration of Penult and Antepenult syllables.

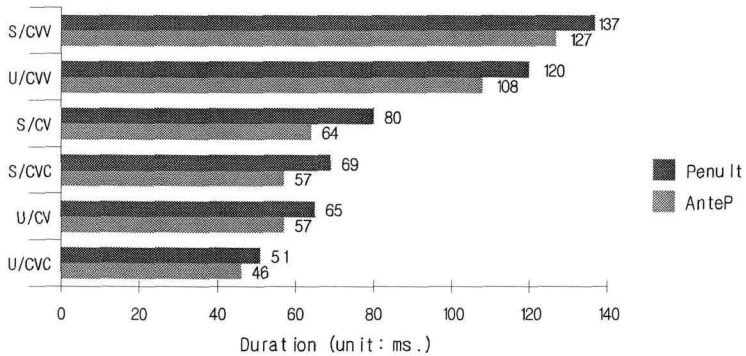

Figure 1 shows that a vowel of stressed penult CVV syllables is the longest among others, due to the accumlative effect of stress induced lengthening, penultimate lengthening without closed syllable shortening. On the other hand, a vowel of unstressed antepenult CVC syllables is shortest among them, due to closed syllable shortening and no benefit of stress induced and positional lengthening. Vowel duration of each syllable in Figure 1 arises from the accumulative effect of the three phonetic lengthening/shortening and its own phonemic vowel length. Figure 1 is exactly what I predicted in (3) in Section 2.

4.5. Discussion

The statistical analyses demonstrate that all four hypotheses are true: stressed vowels are longer than unstressed vowels; vowels in open syllables are longer than vowels in closed syllables; and vowels in penultimate position are longer than vowels in antepenultimate position; three phonetic lengthening effects are accumlative. All results are fully consistent with the proposed theory.

The experiment shows the extreme vowel lengthening of stressed penultimate CV syllables, and also possible neutralization of phonemic contrast of vowel length. It is well known that phonological durational distinction between vowels is marked by a temporal ratio of 2:1 or more in languages with phonemic vowel length, and that the durational difference is the primary cue to identifying the contrast of vowel length (Hadding-Koch & Abramson, 1964; Lehiste, 1970; Jensen & Menon, 1972; Janson, 1979; Keating 1985). As seen in the previous section, in JA the

duration ratio of long and short vowels is 2.1:1 on average. However, stressed CV syllables in the penultimate position seem to put the phonemic contrast of CV syllables with CVV syllables in jeopardy.[14] Vowels in stressed CV syllables are 80 ms long on average, while vowels in unstressed CVV syllables are 120 ms. long on average. The differnce is 40 ms. and the duration ratio is 1.5 : 1, which is much lower than the average 2.1:1 ratio. Unstressed long vowels are just 1.5 longer than stressed short vowels in a CV syllable in penultimate position. The durational difference of long and short vowels becomes much smaller when stressed penultimate CV (80 ms.) and unstressed antepenultimate CVV sylalbles (108 ms.) are compared. The difference is 28 ms. and the ratio is 1.4 : 1. On the other hand, the vowel duration ratio of unstressed CVV and stressed CV syllables is 1.7 : 1. in antepenultimate position, When vowels in stressed CVC syllables and in unstressed CVV syllables are compared, the duration ratios are 1.7:1 in penultimate and 1.9 : 1 in antepenultimate position. The ratios surely indicate that the phonemic contrast of vowel length is sustained better in antepenultimate position than in penultimate position and better in between CVV and CVC syllables than between CVV and CV syllables.

The comparison of vowel duration between unstressed long open vowels and stressed short open vowels suggests that the difference may not be sufficient enough to cue a phonemic contrast in vowel length. Unstressed penult open long vowels are only 40 ms. longer than stressed penult open short vowels, and unstressed antepenult open long vowels are only 28 ms. longer than stressed penult open short vowels. Considering the fact that the same short vowels in unstressed CVC and stressed CV syllables even differ by 29 ms in terms of duration, the 40 ms. or 28 ms. seems not long enough to mark contrast between long and short vowels. Lehiste (1976, p. 226) reports that the psycophysical threshold for just-noticeable differences in duration between two sounds is between 10 and 40 ms., even though just-noticeable differences in duration varies depending on the segmental quality, the word size, and the syllable position within a word, and intensity (Lehiste, 1970; Huggins, 1972; Klatt & Cooper, 1975; Nooteboom, 1973). Klatt (1976, p. 1218) asserts that the duration difference between long and short vowels should be much

14) Generally, stress in JA does not fall on penultimate CV syllables, but it does only in di-syllablic words or tri-syllabic words with initial unstressable definite article '*il*'.

greater than just-noticeable difference since duration is the primary cue for the contrast between long and short vowels. Therefore, in Jordanian Arabic, we predict that it may not be easy to perceive the vowel length contrast in unstressed CVV and stressed CV syllables.

5. CVC Syllables in Final Position

In Jordanian Arabic, stress primarily falls on the final syllable if it is a CVVC, or CVV syllable. If no such syllable in the final position, then stress falls on the penultimate syllable unless it is CV syllable. CVC syllables are stress attractors in the penultimate position, but not in the final position. In the phonology literature (Hayes, 1995), the same stress pattern is analyzed as a quantity-sensitive system which locates stress on heavy CVV and CVC syllables over light CV syllables, in conjunction with consonant extrametricality by which the word-final consonant is exempt from the metrical parse. The final consonant C in CVC syllables in the final position is invisible to the metrical parse so that the CVC syllables count as CV syllables. This is why CVC syllables do not bear stress in the final position, according to the previous analysis.

Liberman and Prince (1977) first proposes that a peripheral syllable can be left out of the metrical scansion, making it extrametrical. Prince & Smolensky (1993) propose non-finality which requires that the prosodic head of the word does not fall on the word-final syllable. In addition to the final syllable, various types of extrametricality such as segment, consonant, vowel, mora, syllable, light syllable, foot, and light foot extrametricality have been suggested from language to language, depending on the stress pattern (van der Hulst 1999, p. 30). However, it should be questioned if all types of extrametricality are really necessary, what motivates each of them, and how they are grounded phonetically and phonologically. Hyman (1977) suggests that penultimate stress is preferred since pitch change, one of the major cues of stress, can be expressed over the last two syllables. According to Hyman, final stress is less preferred than penultimate stress in terms of the realization of pitch, since word-final syllables tend to weaken. However, other types of extrametricality have never been accounted for in terms of their phonetic and phonological functions.

I attribute the stress pattern in the final position to a strategy to make

a good contrast of stress as well as vowel length. The extreme lengthening of final syllables makes even a short vowel in both CVC and CV syllables long enough to jeopardize the phonemic contrast with long vowels, and makes a bad stress contrast.

First, the data from the experiment show that final lengthening is more extreme than penultimate lengthening in Jordanian Arabic. Stressed CVV, unstressed CV and unstressed CVC syllables can occur in all three final, penultimate, and antepenultimate positions. Table 2 presents the comparison of vowel duration in the three positions: while a penultimate vowel is 10 % longer than an antepenultimate vowel on average, a final vowel is 40 % longer than an antepenultimate vowel on average.

Table 2. Vowel Duration in Final, Penultimate and Antepenultimate Positions

	Final	Penult	AnteP
S/ CVV	173 ms. (1.4)	137 ms. (1.1)	127 ms. (1)
U/ CVC	73 ms. (1.4)	51 ms. (1.1)	46 ms. (1)
U/ CV	81 ms. (1.6)	65 ms. (1.1)	57 ms. (1)
Average	109 ms. (1.4)	84 ms. (1.1)	77 ms. (1)

Under such an extreme final lengthening condition, we can expect that if the final CVC and CV syllables are stressed, the stressed vowel duration would reach almost the average duration of unstressed long vowels in penultimate position or in antepenultimate position. Unstressed CVC and CV syllables in final position are 73 ms. and 81 ms. long and unstressed CVV in penultimate and antepenultimate position is 120 ms. and 108 ms. long in average vowel duration. It is true that phonemic vowel length can manifest variably depending on the position. Yet, it is not desirable that two segments which are phonemically different only in terms of vowel duration would have the chance to realize the same vowel duration, even if they are in two different positions.

Stressed final CVC and CV syllables will not have a good stress contrast and phonemic vowel length contrast under extreme final lengthening conditions, when they are adjacent to penultimate unstressed long vowels. Stress is defined syntagmatically rather than paradigmatically. Segmental features like [nasal], [high], [voice] and [continuant] contrast paradigmatically: /tap/ and /tab/ contrast with each other because the third segment of

the second word /tab/ has a [voice] feature which the first word does not. On the other hand, a stressed syllable is defined only by the adjacent unstressed syllable, which is less prominent. Stressed syllables cannot be defined by themselves and therefore the minimum unit for stress is a bi-syllabic morpheme (Beckman 1986).[15] It points to an important point to the stress pattern in Jordanian Arabic. Given that stress is marked by increased duration, increased intensity, and pitch change, the final positions are only good for manifestation of increased duration because intensity and pitch change do not realize well in final position due to the final weakening effect. However, the increased vowel duration does not make a good syntagmatic perceptual contrast when a stressed short vowel follows a long vowel. This may be why stress avoids a short vowel, whether it is closed or open, in a language with the extreme final lengthening effect.

I claim that the avoidance of stress on the final short vowel in CVC and CV syllables arises from strategies to make a good mark for stress and to make a good phonemic contrast of vowel length in the whole phonemic paradigm of the given language. Accordingly, stress in Jordanian Arabic targets primarily the final position, and then the penultimate position, and then antepenultimate position. Stress targets in Jordanian Arabic are basically the word-final position, not specific syllable types such as long voweled syllables or closed syllables.

6. Conclusion

This study demonstrates that the notion of syllable weight relevant for stress is not solely phonologically grounded as has been assumed generally. Rather it is grounded in the interplay of phonetic duration and the notion of contrast preservation in phonology.

The results of the experiment show that in Jordanian Arabic, stressed vowels are longer than unstressed vowels in all positions and all types of syllables; open vowels are longer than closed vowels in all positions and both stressed and unstressed conditions; and vowels in penultimate

15) See Beckman (1986) for the difference between stress accent and tone and the difference between stress accent and non-stress accent. In this article, stress does not stand for pitch-accent.

position are longer than vowels in antepenultimate positions in all types of syllables. All results converge on the point that vowels in stressed penultimate CV syllables have a great chance to lose their phonemic contrast with long vowels due to positional, syllable-structural, and stress-induced lengthening effects. It may be true that Jordanian Arabic does not use a great degree of changes in vowel duration to mark stress, closedness of a syllable and position within a word, when compared with languages without phonemic vowel length. Yet, the lengthening effects by stress, position and openness of a syllable have been found accumulative, which make vowels in stressed penultimate CV syllables have a chance to neutralize their phonemic contrast with long vowels. Data from the experiment reveal that the difference in vowel duration between unstressed CVV and stressed penult CV syllables in the penultimate position is reduced to about 40 ms, in the same penult position, and about 28 ms. in the antepenult position.

In conclusion, the notion of syllable weight relevant for stress could be defined in terms of the interaction of phonetic duration and the notion of contrast preservation in phonology, rather than as an abstract concept of phonology. This study illuminates the area, by questioning how three phonetic expressions of stress, pitch, duration and intensity, are interrelated with phonological stress patterns. Even if it may not be easy to prove directly whether the proposed theory is true or false, the phonological distributions of CVV, CVC, CV syllables in stress systems and three phonetic lengthening effects converge on the proposed theory.

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Appendix

			ST	UT
		C(CVVC)	?ilbilaad (the countries)	
F	L	O (CVV)	?ilṣalaa (the prayer)	
		C (CVC)		?ilmaktab (the office) ?ilbalad (the country)
	S	O (CV)		salaTa (salad) ?ilxaala (the aunt)
		C(CVVC)	kutaabkum (your clerks) bilaadkum(your contries)	
P	L	O (CVV)	maTaabix (kitchens) ?ilDaabiT (the office)	kabaabiit (coats) ?ilsaabuun (the soap)
		C (CVC)	?ilTabxa (the cooked dish) ?ilbadleh (the suit)	?ilTabxaat (the cooked dishes) ?ilsallaat (the baskets)
	S	O (CV)	?ilbagar (the cattles) ?illaben (the yogurt)	?ilTabiib (the doctor) ?ilshabaab (the young guys)
		C		
	L	O (CVV)	Taabi9a (a typewriter) Saamiya (girls name)	Taabi9aat (typewriters) saabuunna(our soaps)
A		C (CVC)	madrasa (a school) takara (a ticket)	Tabxaatna (our cooked dishes) sallaatna (our baskets)
	S	O (CV)	salaTa (salad) shazara (a tree)	Tabiibkum (your doctor) sanaadiig (boxes)

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