

ACOUSTIC CORRELATES OF ARAPAHO PROMINENCE

by

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Abstract

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Correlates of Arapaho Prominence

Thesis directed by Professor Andrew Cowell

The Arapaho language (one of the Plains Algonquian languages of the Algic family) is traditionally claimed to be a pitch-accent language, meaning that prominence is marked exclusively or mainly by modulation of fundamental frequency (Goddard 2001, Cowell 2008). The main goal of the current research was to experimentally establish the phonetic difference between accented and accentless vowels in Arapaho. The present study assesses Arapaho prominence with six acoustic variables: pitch peak of the target vowel (F0, fundamental frequency) and average pitch throughout the target vowel, which are measured in Hertz (Hz); amplitude peak and average amplitude throughout the vowel (in dB); duration (in ms), and spectral quality of the vowel (peripheral versus central, i.e. precision of articulation, F1, F2, F3). Contrary to the traditional analysis of this language, Arapaho can hardly be called a pitch-accent language. While accent in short vowels is marked with significantly higher fundamental frequency and higher amplitude, accent in long vowels is cued by longer duration. From the phonetic point of view, Arapaho functions more like a stress-accent system that deploys a set of phonetic cues to mark prominence. Phonologically, prominence in Arapaho does not function like stress in the traditional interpretation of the term – the system exhibits severe breaches of the principle of culminativity. At the same time, I show that accent in Arapaho might function very much like accent in stress systems in that it is a morpho-lexical feature; the accent shifts depending on morphemic, morphological, and lexical properties. The data presented in the study call for a revision of the notion of stress-accent systems in the typology of prosodic systems.

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Contents

Abstract	iii
Figures	viii
List of abbreviations	ix
Chapter 1. Introduction	1
1.1 Objectives and goals	2
1.2 Terminology	2
1.3 Thesis Outline	3
Chapter 2. Overview of the Arapaho language	5
2.1 Socio-Cultural Outline	5
2.2 Arapaho Phonology	8
2.2.1 The Arapaho Word	8
2.2.2 Arapaho phonemic inventory	9
Chapter 3. Typology of Word-Prosodic Systems	12
3.1 Stress Systems	13
3.2 Tone Systems	19
3.3 Pitch-accent	21
3.4 Issues with the Existing Typology	24
3.4.1 Pitch-accent vs. Stress	24
3.4.2 Pitch-accent vs. Tone	32
3.4.3 Stress vs. Tone.....	34
3.5 Brief Conclusions	35
Chapter 4. Pitch-Accent and Arapaho	38
4.1 Arapaho Prominence	38
4.2 Data	41
4.3 Experimental Procedures	42
4.4 Prominence and F0	45
4.5 Prominence and duration	47

4.6 Prominence and quality of the vowel	51
4.7 Prominence and amplitude	59
Chapter 5. Statistical analysis	65
5.1 Results of statistical tests	65
5.2. Discussion	70
Chapter 6. Conclusions.....	74
References.....	78
Appendices.....	84
Appendix 1.	85
List of words read by the Arapaho speaker (accented target vowels)	85
Appendix 2.	88
List of words read by the Arapaho speaker (unaccented target vowels)	88

Tables

Table

1. Phonemic inventory of Arapaho consonants.....	18
2. Phonemic inventory of Arapaho vowels.....	19
3. Accented-accentless counterparts for the comparison of acoustic features of accented /e/ vs. unaccented /e/.....	54
4. Mean F0 of short accented and accentless vowels.....	56
5. Mean F0 of long accented and accentless vowels.....	56
6. Mean duration of long accented and accentless vowels.....	58
7. Mean duration of short accented and accentless vowels.....	58
8. Mean F1, F2, F3 for short accented and accentless vowels.....	62
9. Mean F1, F2, F3 for long accented and accentless vowels.....	62
10. Mean intensity values of accented vowels and vowels in the preceding syllable.....	69
11. Comparison of intensity of an accented vowel and the vowel in the preceding syllable.....	69
12. Characteristics of the accentual system of Arapaho.....	78

Figures

Figure

1. Selected Algonquian languages (adapted from Campbell 1997, 361).....	16
2. Laryngealized /x/ and associated with it high pitch contour.....	53
3. Vowel interval for duration measurements.....	58
4. “Extreme” reduction patterns.....	62
5. “Moderate” reduction patterns.....	62
6. Formant qualities of accented and unaccented long and short vowels.....	63
7. Formant values of accented and unaccented long and short /i/.....	64
8. Formant values of accented and unaccented long and short /e/.....	65
9. Formant values of accented and unaccented long and short /o/.....	65
10. Formant values of accented and unaccented long and short /u/.....	66
11. Quality reduction of the Arapaho vowels.....	68
12. Comparison of intensity of an accented vowel and the vowel in the preceding syllable....	72
13. Comparison of intensity of an accented vowel and the vowel in the preceding syllable....	73
14. Mean duration in ms for accented and unaccented short and long vowels.....	76
15. Mean fundamental frequency in Hz for accented and unaccented short and long vowels..	77
16. Mean fundamental frequency peak in Hz for accented and unaccented short and long vowels.....	78
17. Mean amplitude in dB for accented and unaccented short and long vowels.....	79
18. Amplitude peak in dB for accented and unaccented short and long vowels.....	80

List of abbreviations

Acc.	Accusative case
C	Consonant
Dat.	Dative case
dB	Decibel
Gen.	Genitive case
H	High level tone
Hz	Hertz
Imperf.	Imperfective verb form
Infinit.	Infinitive verb form
L	Low level tone
M	Mid level tone
MaxAmp	Maximum amplitude
MiddleV	Middle voice
Ms	Millisecond
N	Noun
Neg	Negative
Nom.	Nominative case
Pl	Plural
Pres.	Present Tense
S	Singular
V	Verb
V	Vowel

Chapter 1. Introduction

This thesis examines acoustic correlates of prominence in the Arapaho language. This language is traditionally claimed to be a pitch-accent language, meaning that prominence is marked exclusively or mainly by modulation of fundamental frequency. Assignment of the Arapaho language to the group of the pitch-accent languages also signals a rather ambiguous status of this system in the word-prosodic typology. On one hand, all claims about the physical nature of cues of accent in the Arapaho language were based on impressionistic data only. No experimental phonetic analysis has ever been done to determine whether change in pitch is in fact correlated with accent in this language. On the other hand, the Arapaho language does not particularly fit into either the group of stress languages or tonal languages. If it were to be analyzed as a tonal system, it would be a rather deficient one. This language has only one level tone – high tone, contrasted with neutral tone, no-tone syllables. Arapaho can hardly be called a prototypical stress language either. The system exhibits regular violations of the principles of culminativity and obligatoriness of stress allowing for up to five accented syllables per word¹ as well as for unaccented words (mostly categorical). Empirical investigation of the phonetic cues of accent together with a closer look at the typological surveys of word-prosody will allow for a more precise description of the Arapaho language.

¹The phonetic and phonological status of multiple accents in the Arapaho language requires close investigation which would include answering such questions as: Are all the accented syllables in a word equally prominent? Is the distinction between primary-accented and secondary-accented syllables relevant for that system? If this distinction is relevant, what phonological rules govern the assignment of accents, and what is the phonetic difference between different levels of prominence? These questions are out of scope of the present study. It is however important to notice that an Arapaho word can have up to five accents as part of the lexical representation, i.e. this language can have multiple accents assigned on the lexical level which differs from, for instance, English, where “additional” accents are assigned on post-lexical level.

1.1 Objectives and goals

The main goal of the current thesis is to determine the acoustic correlates of prominence in the Arapaho language. In other words, this thesis is meant to experimentally establish the phonetic difference between accented and accentless vowels in Arapaho. This research aims to investigate the status of pitch-accent system that is traditionally assumed for this language. Several questions will be explored to examine the prominence of Arapaho:

- Does higher pitch correlate with accent?
- Do other phonetic cues (i.e. duration, spectral quality, intensity) play any role in designating the prominence? And, if so:
- What is the hierarchy of accent cues in Arapaho?
- Is the accent cued in the same way for different kinds of vowels in the language (natural classes of vowels, long vs. short vowels)?

The structure of this thesis will be outlined below, showing how these questions will be examined through the presentation of an empirical study and of a relevant body of literature concerning the issues of word-prosodic typology and experimental methods of studying phonetic correlates of prominence. Before presenting this outline, however, it is necessary to define the terminological apparatus used in the thesis.

1.2 Terminology

Word-prominence is the main focus of this thesis; therefore the specific terms used to describe different kinds of prominence should be defined. It will be shown in the following sections that there exists grave inconsistency in usage of such critical terms as *stress* and *pitch-accent*. In this thesis, I adopt the terminological tradition proposed by L. Hyman (1977),

followed by M. Beckman (1986), and H. van der Hulst (2010, 2011). The use proposed by Hyman (1977) takes *accent* as a broad abstract phenomenon, as a generic notion of being prominent, while terms *stress* and *pitch* are used to specify the particular acoustic cues which manifest the accent: “In this practice, then, we adopt ‘compound’ terms of the form ‘X-accent’ where ‘X’ characterizes the cue that correlates with accent. Hence ‘pitch-accent’ means: the accent is cued by pitch” (Van der Hulst 2010, 11). The term *stress-accent* then means: accent is cued by a number of phonetic variables that are usually associated with prominence in languages like English or Russian – duration, intensity, fundamental frequency, and spectral quality.

If tone is used distinctively in a language (and not for marking prominence), the term *tone language* is used. Further discussion of phonetic and phonological properties of stress-accent (henceforth, *stress*), pitch-accent, and tone languages as well as of other terminological practices is provided in Chapter 3 of the current research.

1.3 Thesis Outline

The thesis consists of six chapters, including Introduction and Conclusion. In Chapter 2, I will briefly touch on relevant socio-cultural data about the Arapaho language. I will also introduce the important features of the structure of a word and of the phonemic inventory in this language. Examination of different typological kinds of word-prosodic systems begins in Chapter 3. Chapter 3 provides a review of literature related to acoustic and distributional properties of three types of prosodic systems traditionally addressed in the scholarship of the field – Stress systems, Tone systems, and Pitch-Accent systems. In the last section of Chapter 3, I will summarize the existing inconsistencies in the word-prosodic typology and outline the difficulties with delimitating stress, tone, and pitch-accent languages. That section deals with the issues of obligatoriness and culminativity of stress, distributional features of pitch in tone and

pitch-accent languages, as well as with the notion of functions of suprasegmentals in different prosodic systems. Chapter 4 starts with a brief discussion of the existing data about phonetics and phonology of prominence in Arapaho. The focus of this Chapter is the experimental investigation of the phonetic cues of accent in the Arapaho language. A detailed description of the experimental procedures is provided. Each section of Chapter 4 addresses one of the possible acoustic correlates of accent – duration, change in fundamental frequency, intensity, and spectral quality of the vowel. Chapter 5 provides description and results of statistical analysis undertaken to test significance of the observations and measurements given in Chapter 4. The conclusions and paths for further research are proposed in Chapter 6.

Chapter 2. Overview of the Arapaho language

This chapter presents a brief outline of the relevant socio-cultural and linguistic information about the Arapaho language. It situates Arapaho among other languages of the Algonquian family and provides relevant information about the structure of a word in Arapaho as well as a general overview of the phonemic inventory of this language.

2.1 Socio-Cultural Outline

The Arapaho language (also spelled Arapahoe or Arrapahoe) is a member of the Plains branch of Algonquian portion of the Algonquian family. Languages of this family are or were widely spoken on the eastern seaboard, northeast and upper Midwest of the US, and in eastern Canada. The Algonquian family covers the largest territory of all North American language families (Mithun 1999, 328). Presented below is the classification of the languages of the Algonquian family (see Campbell 1997, 153; Mithun 1999, 327):

California Algonquian (Ritwan) Languages

Wiyot

Yurok

Eastern Algonquian Languages

Abenaki-Penobscot (Dialects: Abenaki and Penobscot)

Maliseet-Passamaquoddy (Dialects: Maliseet and Passamaquoddy)

Mi'kmaq (Micmac)

Lenape-Renape Languages

Delaware (Lenape)

Munsee

Nanticoke

Mohican-Loup Languages

Mohican (Mahican/Stockbridge)

Mohegan (Pequot)

Narragansett

Wampanoag (Massachusett)

Central Algonquian Languages

Cree-Innu Languages

Attikamekw (Tete de Boule)

Cree

Montagnais

Naskapi

Ojibwan Languages

Algonkin (Algonquin)

Ojibwe (Chippewa, Ojibwa, Ojibway, Anishinabemowin)

Ottawa (Odawa)

Kickapoo

Menominee

Mesquakie-Sauk (Sac and Fox)

Miami-Illinois

Potawatomi

Shawnee

Plains Algonquian Languages

Arapahoan Languages

Arapaho

Gros Ventre (Atsina)

Blackfoot (Siksika, Peigan, Blackfeet)

Cheyenne

Arapaho is one of a group of Algonquian languages spoken on the Great Plains (**Plains Algonquian Languages**). Related to Arapaho are Cheyenne, Blackfoot and Gros Ventre. The map below represents the spread of the Algonquian languages.

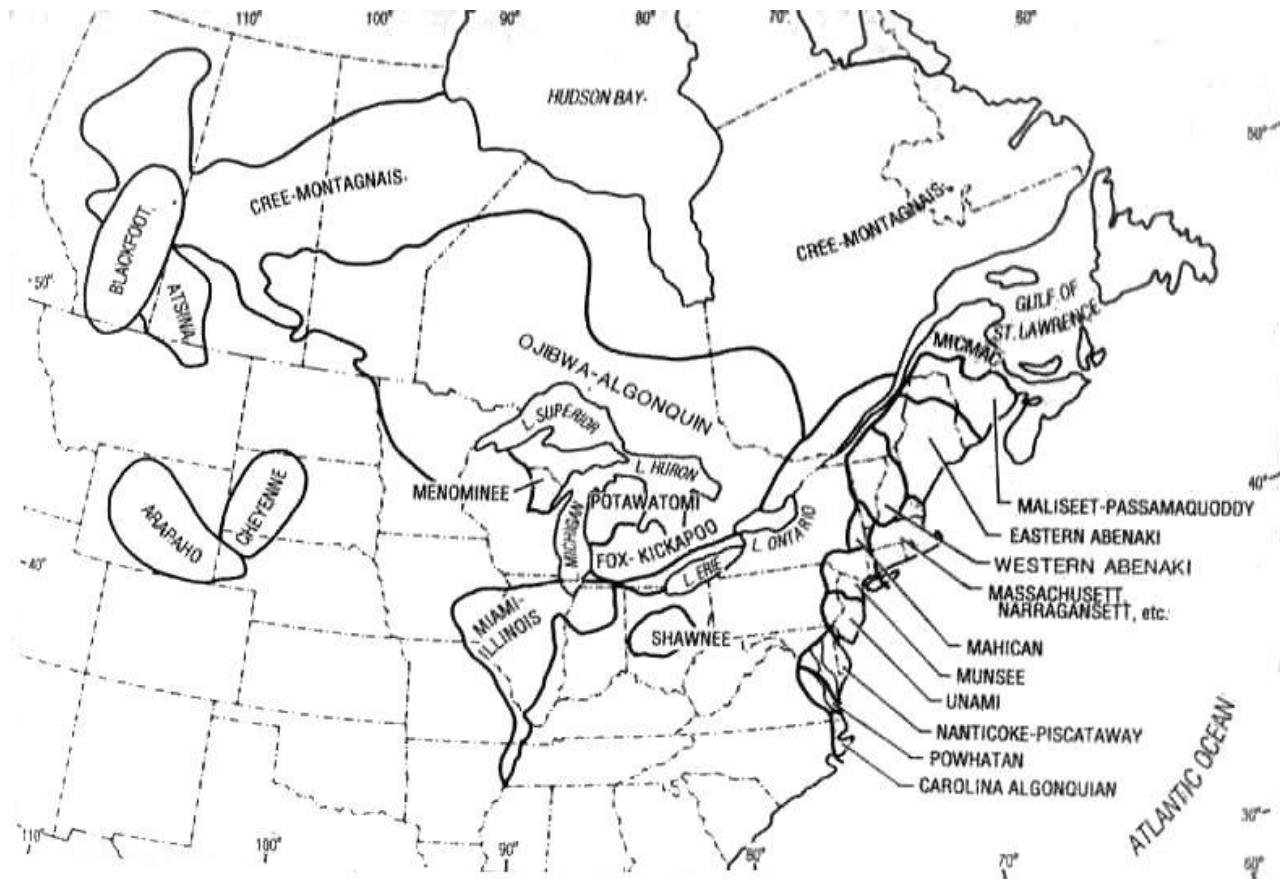


Figure 1. Selected Algonquian languages (adapted from Campbell 1997, 361)

The Arapaho language is endangered. It is currently spoken fluently by fewer than 300 speakers in their late fifties and older. Most, if not all, remaining Arapaho speakers are bilingual speakers of English. Although attempts are being made to revitalize the language, few children speak Arapaho fluently (for a detailed discussion of the Arapaho revitalization project see Greymorning 1997, Hale 2001). The Arapaho language is spoken in two closely related dialects. Northern Arapaho is spoken on the Wind River Reservation in Wyoming, and Southern Arapaho “is spoken fluently by only a handful of people in and around western Oklahoma” (Cowell 2008, 1).

2.2 Arapaho Phonology

In order to establish the necessary basis for discussion of the prosodic system of Arapaho, the following section outlines the relevant characteristics of Arapaho word structure and phonemic inventory. For further discussion on Arapaho phonology, see Goddard (1974), Goddard (2001), Cowell (2008).

2.2.1 The Arapaho Word

Arapaho is a polysynthetic language; most information is encoded morphologically onto the verb stem. The verb stem may morphologically encode agreement markers, such as person and number markers; adjuncts, such as question markers, negative markers; tense; mode and aspect. “The verb can be roughly described as potentially including the following elements in the following order:

PROCLITIC + PERSON MARKER + TENSE/ASPECT/MODE PREVERB + LEXICAL PREVERB + VERB STEM + DIRECTION OF ACTION THEME + PERSON/NUMBER SUFFIX + MODAL SUFFIX” (Cowell 2008, 62).

(1)

Koo - né -ih -nosou -bixóó3 -ei -be
Inter. - 1S -Past -still -love (TA) -inv. -pl
Did they still love us?

The example in (1) shows that an Arapaho word can have a very complex structure. Since this language tends to put as much information as possible in the verb, “many Arapaho sentences in both conversation and narrative consist only of a verb” (Cowell 2008, 62). This verb then functions as a one-word phrase and usually is translated into English with a whole sentence (as in the example (1) above). The status of a word in Arapaho is completely unstudied, and the issue of delimiting word- and phrase-prosody is especially problematic for a language like Arapaho.

2.2.2 Arapaho phonemic inventory

Arapaho has a somewhat limited phonemic inventory. It has twelve consonants, four vowels with contrastive length, and three diphthongs also with contrastive length. The inventory of consonants (with the standard orthographic form) is represented in Table 1. Arapaho contrasts six places of articulation for consonants, including labials, dentals, alveolars, palatals, and laryngeals. Consonants are also distinguished along five manners of articulation: plosive, fricative, affricate, nasal, and glide. Arapaho lacks liquids; voicing and length are not contrastive for the consonants in Arapaho.

	Labial	Dental	Alveolar	Palatal	Velar	Glottal
Plosive	b (b)		t (t)		k (k)	ʔ (‘)
Fricative		θ (3)	s (s)		x (x)	h (h)
Affricate				tʃ (c)		

Nasal			n (n)			
Glide	w (w)			j (y)		

Table 1. Phonemic inventory of Arapaho consonants

A. Cowell points out that “all consonants can occur initially, intervocalically, and finally, although the glottal stop occurs initially only in a few emphatic particles, and (non-phonemic) /h/ occurs initially only as a result of underlying vowel-initial forms” (Cowell 2008, 83).

Arapaho has only four phonemic vowels, represented in Table 2 with the standard orthographic correspondents:

i (i)	u (u)
ε (e)	ɔ (o)

Table 2. Phonemic inventory of Arapaho vowels

These vowels can occur in two contrastive lengths, short and long (examples adapted from Cowell 2008, 85):

(2)

hísi' – híisi'

hócoo – hóócoo

bís – bíís

tick – day

steak – devil

all – hairy

Arapaho also has four diphthongs: /ei/, /ou/, /oe/, and /ie/, the last being “marginally a diphthong” (Cowell 2008, 86). Length is contrastive in diphthongs as well (examples adapted from Cowell *ibid.*):

(3)

hou – houu

bei – beií

blanket – crow needle – shell

Arapaho allows for three-vowel sequences to occur “either with a single vowel, such as *hóoó* ‘bed’ or with two or three different vowels, such as *hihéío* ‘his aunt’” (Cowell 2008, 86). Phonological status of the three-vowel sequences is not studied thoroughly. This thesis does not address the nature of these sequences. Acoustic and phonological properties of the three-vowel combinations would be an interesting topic for a further research.

Chapter 3. Typology of Word-Prosodic Systems

This chapter provides an overview of the contemporary analyses of the ways in which word prosody can be organized in a language. Such overview is necessary for understanding of the ambiguous status of the Arapaho language in the existing typology.

Most scholars nowadays assume that there are three typological kinds of prosodic systems in the languages of the world: Tone Systems, Stress Systems and Pitch-Accent Systems. It has been noticed that it is problematic to draw sharp lines between classes of prosodic systems: “The question of whether a description of the prosodic system of some undescribed language should be framed in terms of “stress”, “accent” or “tone” (and the justification for a particular choice in a language with a descriptive tradition) has plagued the workaday linguist for years...” (Odden 1988, 225). Pitch-accent systems are usually considered to be intermediate between the “pure” stress systems and the “pure” tone systems. In this chapter, I try to present a thorough summary of the theoretical and empirical descriptions of these three types of prosodic systems. I describe the main phonological and phonetic features of each system as presented in the existing scholarly literature. As a conclusion to this chapter, I will discuss the issues that modern classification inspires and the main problems with the procedure of assigning languages to one or another type of system in the typology. The structure of this chapter is as follows: In section 1, I will introduce the notion of a stress system; I will discuss the main phonetic and phonological features of this type of prosodic organization. In section 2, I will present the acoustic and distributional properties of tone systems as described in scholarly literature. Section 3 focuses on characteristics of pitch-accent systems. In section 4, I present an overview of the issues that arise when we try to delimit (1) pitch-accent systems from stress systems; (2) pitch-accent systems

from tone systems; (3) stress systems from tone systems. Finally, in section 5, I will offer some general conclusions.

3.1 Stress Systems

Word Stress is the relative emphasis on one of the syllables in a word. “Syllables that form a word are not equal if the word contains more than one syllable. One of the syllables is marked among others by some special phonetic properties. This type of prominence is called *stress*, or to be more precise *word stress*, or *lexical stress*²” (Avanesov 1956, 61). D. Fry proposed the following definition: “Stress is a term that refers to a relation between syllables; and successive variations in this relation constitute the rhythmic pattern of an utterance just as successive variations in tone-relations make up the intonation pattern” (Fry 1958, 127). Stress can be either lexical or fixed. Lexical stress is encoded in a lexicon; it is an invariant part of a word. That means that lexical stress is unpredictable and has to be learnt together with the word. Fixed stress, on the other hand, is fully predictable and usually falls on one specific part of all words in a language (Van der Hulst, 1999).

From *the phonological point of view*, a prototypical *stress system* is the one in which syllables in a word are metrically hierarchized as relatively strong vs. weak (Hyman 2009, Bondarko 2004, Stacy 2004, Zenskaya 1983 among others). In terms of distribution of stressed syllables, such a system would meet “the two core criteria:

1. Obligatoriness: every lexical word has at least one syllable marked for the highest degree of metrical prominence (primary stress);
2. Culminativity: every lexical word has at most one syllable marked for the highest degree of metrical prominence” (Hyman 2009, 217).

² I should notice that this definition can also describe pitch-accent.

These two central criteria mean that ‘every prosodic word contains one and only one head foot, which is the locus of main stress. “The existence and uniqueness of the head foot are usually taken to be axiomatic – universal properties rather than violable constraints” (McCarthy 2003: 110). In a prototypical stress language, “metrical structures have one designated terminal unit, the head of the word, which counts as the (primary) ‘stress’” (Van der Hulst 2011, 1006). The phonological function of the stress is then (1) metrical – in the sense that it creates the metrical hierarchy on the word level – and (2) “contrastive in the sense that it’s presence on one stress-bearing unit implies it’s absence elsewhere” (Hyman 2009, 216). M. Halle and J.-R. Vergnaud proposed the following crosslinguistic generalizations concerning distribution of stress. These proposed universalities suggest that in the frame of metrical theory of stress the distinction between “prototypical” stress systems (as defined by Hyman 2009) with culminative stress and non-prototypical systems with multiple stresses is not accounted for:

“a. Not all phonemes may bear stress; different languages select specific subsets of phonemes to bear stress.

b. In some languages, every word has one and only one stress.

c. In some languages, every word has at least one stress but may have more than one.” (Halle, Vergnaud 1983, 3).

Apart from constraints and rules of distribution of the stressed syllables, another important phonological criterion is the difference in feature combinations allowed for stressed and unstressed syllables in languages. It’s been noted that “accented syllables allow more complexity in terms of the feature combinations that make up segments” (Van der Hulst 2010, 6). For example, if there is a length contrast among vowels of a language, it might be the case that

the contrast would only appear in the accented syllables, unaccented syllables allowing only short vowels. Variety of syllable structures can be used as another example. “In languages that allow more than just CV, it is not untypical to find that only accented syllables display the full array of syllable types that is allowed by the language” (Van der Hulst 2010, 8).

Hierarchical character of stress is another important phonological property of this type of prosodic organization: “Stresses in connected speech occur with varying degrees of prominence” (Cruttenden 1997, 17). Prominence in a stress system contrasts a syllable to neighboring syllables so as to organize them into words. At the same time, “it can be a feature of a larger pattern that contrasts words within phrases and smaller phrases within larger phrases, creating an ever larger organizational structure up to the level of the entire utterance” (Beckman 1986, 64). In addition to metrical and contrastive functions mentioned above, stress then has an organizational, hierarchical function.

Phonetically, the prominence of a stressed syllable in a stress system is usually cued with some combination of acoustic properties such as length, intensity (or loudness), pitch, and vowel quality. “Preciseness of articulation, spectral tilt, duration, amplitude, energy and pitch are all ‘stretchable’ properties that all vowels (indeed all segments) have to some degree, but it would seem that the accented vowels have all of these to the greatest degree.” (Van der Hulst 2010, 4). D. Fry pointed out that the term *stress* refers simultaneously to articulation and to perception. “Differences of stress are perceived by the listener as variations in a complex pattern bounded by four psychological dimensions: length, loudness, pitch and quality. The physical correlates of these perceptual factors are the duration, intensity, fundamental frequency and formant structure of the speech sound waves” (Fry 1958, 126). Depending on what the main cue is, some phoneticians distinguish between three main types of stress. *Dynamic stress* is present when the

accented syllable is articulated with the strongest tension in the articulatory apparatus. It should be noted, that there is no clear point of view on what kind of phonetic system should be considered a dynamic-stress system. This term was normally used in the literature to suggest that energy and/or amplitude were the main cues of stress. R.I. Avanesov claimed that a vowel carrying dynamic stress differed from unstressed vowels mainly due to significant tension in the articulatory apparatus, so that the vowel is articulated more deliberately (Avanesov 1956). We can also encounter a different definition: “Dynamic stress presupposes increase of intensity of a sound as the main cue of stress” (Bondarko et al. 2004, 120). In some older works on stress, dynamic stress was called *expiratory*, because of the idea that the intensity of expiration is the most important cue to a stressed vowel. Later, it was proven that “the term *dynamic stress* does not reflect the acoustic specifics of stress, as whatever the main cue of stress is, the stressed vowel is perceived as the strongest. Therefore, this term is not accurate from the perceptive point of view” (Matusevich , 1973, 121). Moreover, H. Van Der Hulst claims that “the property of amplitude is not used distinctively in any language, so this cue can only be an allophonic manifestation of accent, and not be involved in a neutralization of contrast situation. The same must be said of energy.” (Van der Hulst 2010, 7). However, some scholars argue that the idea of *dynamic* stress was not completely wrong. A. Sluijter points out that the result of expending more effort in speech production while producing a stressed syllable is not just greater amplitude of the (glottal) waveform. “Increased vocal effort generates a more strongly asymmetrical glottal pulse: the closing phase gets shorter, so that the trailing flank of the glottal pulse is steep. As a result of this, there is a shift of energy over the spectrum such that low frequency components are hardly affected and the energy increase is concentrated in the higher harmonics only (i.e. a change in spectral tilt)” (Sluijter 1995, 6).

The second phonetic type of stress is *quantitative stress*, when the stressed syllable differs from unstressed syllables in the duration of the vowels. Empirical phonetic studies show that the major difference between stressed and unstressed vowels in a lot of languages is that in the duration of vowels (Fry 1954, Garde 1968, Bondarko 1998, Hyman 2006 among others).

And, finally, *qualitative stress*, when the stressed vowels differ from the unstressed vowels because they lack quality reduction, i.e. they are articulated with more precision than the unstressed vowels. Stressed vowels differ from unstressed vowels articulatorily, and hence, spectrally. Emphasis on the stressed syllable causes some specific changes in the unstressed vowels known as *reduction*. “Principles of reduction are of the same type in different languages, namely, contrasting features are not clearly expressed, and the vowels are not clearly differentiated acoustically and articulatorily.” (Bondarko 1998, p. 122). Recent experimental research has shown that Russian can be considered a system with qualitative stress. E. A. Arkhipova empirically proved that “Russian speakers are able to define stress using just one cue – presence or absence of quality reduction” (Arkhipova 2002, 22).

In the existing literature one can find a description of one more type of stress – *tonic* or *musical stress*. Musical stress systems mark the designated unit with the change of pitch or tone. However, “the traditional distinction between musical accent and dynamic accent refers to the difference between pitch-accent and stress-accent languages³.” (Van der Hulst 2010, 11).

The importance of one cue of prominence over the others is always dependent on individual language facts. For example, it has been claimed (Fry 1955, 1958) that in English, the most

³ For a more precise description of pitch-accent systems and the difference between stress systems and pitch-accent systems refer to section 3.4.1 of the current paper.

important cue to stress is a combination of amplitude with duration. In experiments with perception of English stress “when the vowel was long and of high intensity, listeners agreed that the vowel was strongly stressed, when it was short and of low intensity, it was judged as weakly stressed” (Fry 1955, 767). At the same time, difference in duration turned out to be more important than difference in intensity. D. Fry has also shown that a listener “tends to judge a higher syllable as more stressed, but the magnitude of the pitch change makes little contribution to his judgment” (Fry 1958, 144). The most important correlates of the Russian stress are most likely quality and duration (Arkhipova 2002, Bogomolets 2011, Bondarko 1998, Zinder 1979). Cross-linguistically, “in most discussions of stress, a relative ranking of the cues is implied with fundamental frequency considered the most important” (Berinstein 1979, 1). There has been proposed a universal hierarchy of perceptual correlates of stress with change of pitch as the most important cue, greater duration as the second most important correlate, and greater intensity in third place (Bolinger 1958, Hyman 1977). To summarize, cross-linguistically stressed syllables can be characterized with one or several of the following phonetic properties (Van der Hulst 2010, 9):

- a. The syllable has greater duration
- b. The syllable has a balanced spectral tilt
- c. The syllable has greater amplitude
- d. The syllable has a higher fundamental frequency (pitch)⁴
- e. The segments are pronounced with greater precision or extra phonetic traits (such as vowel quality, aspiration).

⁴ L.M. Hyman noticed that there is only one language (in his study of 444 languages of the world) which “has a lowered pitch as a primary cue of word stress” – Chamorro (Hyman 1977b, 74).

Experimental studies of cues of stress in different languages show that “languages differ in the importance of each correlate of stress, and they differ in a non-random way, according to their phonological structure” (Berinstein 1979, 2).

3.2 Tone Systems

A prototypical *tone system* is usually defined in terms of distinctive use of pitch. “Thus, if a language uses pitch to distinguish different otherwise identical morphemes, pitch has a phonological or contrastive (distinctive) status” (Van der Hulst 2011, 1003). The smallest tonal system would have two *level tones*, high (H) and low (L). More extensive systems would add a mid (M) tone and possible two different M tones (high mid and low mid). The number of level tones distinguished in a system is language-specific. L. Hyman claims that a prototypical tone system distinguishes three or more tone levels (Hyman 2009, 217). In addition, systems can have *contour tones*. Contour tones are tones that move from one level to another, for example, from high to low (*falling contour tone*) or from low to high (*rising contour tone*). It is known that “contour tones are commonly restricted to phonemically long vowels” (Hayes 2004, 157). Mandarin Chinese is often used to illustrate contour tones (examples and diacritic designations adapted from Stacy 2004, Hyman 2001):

(4)

- | | |
|-----------------------|----------------------|
| a. High level | má “mother” |
| b. High rising | mǎ “hemp” |
| c. Mid falling-rising | mà “horse” |
| d. High falling | mā “scold” |
| e. Toneless | ma “question marker” |

Examples in (4) illustrate one level tone, one toneless morpheme, and three contour tones.

From the phonological point of view, in a prototypical tone language there is tonal contrast on every syllable of a word. Tone can be either encoded in the lexicon (e.g. Mandarin Chinese, Vietnamese), or assigned by the rules on the word level (African tonal languages such as Mende). “In languages of Sino-Tibetan family, tones are almost exclusively used lexically, with no correlation with the syntactic or morphological aspects of the language” (Wang 1967, 93). If tone is not assigned by a rule, but is encoded in lexicon, this type of tone is called *lexical tone*. *Morphemic tone*, on the other hand, is always predictable from a set of rules⁵. Tone in African tone languages can be dependent on morphological categories and syntactic environment. The two kinds of tonal systems can interact: “Although tone is not rule-governed for the majority of lexical tone systems, it is possible to find subsystems in lexical tone languages where tone is predictable, such as Cantonese [China] hypocoristics where a high tone is found at the end of the word” (Stacy 2004, 21). There are many more tone paradigms in tone languages of Asia. They can have up to five non-contour tones, while for African and American tone languages it is more usual to have “two or three non-contour tones; a relatively small number of these languages have contour tones in addition” (Wang 1967, 94).

Phonetically, the contrast between tone bearing units depends on the modulation of fundamental frequency (F0) that is measured in Herz (Hz). Wang notices: “Though subject to small variations from language to language that have no cognitive import, the range of voice pitch remains remarkably uniform across languages. This is true regardless of how many tones a language has” (Wang 1967, 99). From the *Phonetic* perspective, “no matter how many tones a language has, the voice pitch traverses approximately the same overall range. The difference

⁵ Goldsmith notices that languages with morphemic tone assign “tones through a system of accent placement that look surprisingly like the accent placement that we are familiar with from the stress languages described in the literature” (Goldsmith 1987, 88).

resides in how each pitch value is interpreted vis-a-vis a particular tone paradigm" (Wang 1967, 100). This suggests that tone is relative: "...a phonetic Low tone can often be differentiated from a phonetic High tone only by comparing the two in a specific environment" (Van der Hulst 1993, 1).

3.3 Pitch-accent

Pitch-accent Systems are those which combine the properties (phonetic and phonological) of both stress and tone systems. It is noteworthy that there exists a considerable inconsistency in the linguistic scholarship with respect to what is called a pitch-accent system. "'Pitch-accent' systems freely pick-and-choose properties from the tone and stress prototypes, producing mixed, ambiguous, and sometimes analytically indeterminate systems which appear to be 'intermediate'" (Hyman 2009, 1). In these systems, pitch is non-distinctive, it is used to cue the accent rather than to create a tonal contrast between syllables. The group of the pitch-accent languages is extremely heterogeneous. The term 'pitch-accent' is frequently adopted to refer to a tone system whose tone is obligatory, culminative, privative, metrical, and/or restricted in distribution (Hyman *ibid.*). On the other hand, this term can refer to a 'defective' tone system whose tone is not obligatory, non-culminative, and non-restricted (Van der Hulst 2011). In fact, the body of literature on pitch-accent systems seems to suggest that any kind of mixed and ambiguous prosodic system that employs modulation of fundamental frequency as the phonetic correlate of prominence can be called a pitch-accent system⁶.

⁶ Stacy (2004) distinguishes between *pitch-accent systems* which deploy culminative and obligatory pitch accent, *mixed systems* in which "acoustics from one type of prosodic system may be implemented under the phonology of another type" (44), and *split systems* that have "two unique types of prominence co-existing within the same language" (53).

Phonologically, “there are a number of things that can happen – a restriction on the combination of tones, i.e. the development of a limited number of tone patterns; the replacement of the opposition H-L by the opposition H-Ø, the development of metrical structure (where the designated element is associated with H)...” (Van der Hulst 1988, 21). All of these different prosodic phenomena are characterized as pitch-accent systems. Moreover, it has been claimed that some systems can combine different types of pitch-accent. Chickasaw, a Western Muskogean language spoken in south-central Oklahoma, has been analyzed as having morpho-lexical pitch-accent which only occurs in specific verbs; and “nuclear pitch-accent” which only occurs in a specific position in a phrase⁷ (Gordon 2005). The Blackfoot language is claimed to have lexical pitch-accent (or deficient tone – refer to Stacy 2004 for a detailed discussion) together with discourse-driven pitch-accent, which is “restricted to specific contexts, such as imperatives” and demonstratives (Stacy 2004, 11-12). L. Hyman insists that the existence of such a wide variety of phenomena comes from the nature of pitch-accent systems; they are intermediate, therefore, it is impossible to find a pitch-accent system prototype (Hyman 2009, 3). The ambiguous status of the pitch-accent systems in prosodic typology makes some scholars try to eliminate them as a separate class and take one of the two approaches. Clark (1987) and Pulleyblank (1986) have taken a tonal approach: “rules which insert, delete or change the position of the accent in the pitch-accent model are replaceable, across the board, by tone rules ...” (Clark 1987, 54). Such an approach then says that pitch-accent languages are one sub-type of tone languages. H. van der Hulst (1999, 2010), on the other hand, points out: “If we maintain the term ‘pitch-accent language’, we might then also expect to find languages that can be labeled as

⁷ Chickasaw combines stress and pitch accent in marking prominence. In a system where both stress and accent are present it seems natural that pitch accent is restricted to specific morpho-lexical or phrasal environments. An interesting property of morphologically pitch-accented syllables in this language is that they are always heavy. For a detailed analysis see Gordon (2005).

‘duration-accent’ languages (if duration is the only cue)”. In this approach, pitch-accent languages are seen as being related to stress languages. Clark proposes a four-way classification of prosodic systems of the world: “pitch-accent systems do not fall into a single category, but are split up between classes IB and IIB” (Clark 1988, 51-53):

I. TONAL SYSTEMS

A. Free tone eg. Ewe

B. Restricted tone eg. Mande/Japanese (limited number of tone melodies)

II. METRICAL ACCENT

A. Stress-accent eg. English

B. Metrical pitch-accent eg. Ancient Greek

(realized as H)

In this system, the traditional definition of a pitch-accent language is “split” into two types of systems: IB - ‘deficient’ tone language with only one tonal melody; IIB - a metrical language in which prominence is represented by a high tone. This classification illustrates the ambiguous relations between phonetics and phonology of pitch-accent systems. Although it accounts for systematic difference between languages that are traditionally assigned to the category of pitch-accent languages (i.e. the difference between Japanese and Ancient Greek), it does not provide an efficient tool for classification of languages that can exhibit both limited number of tone melodies and metrical pitch, like Blackfoot (see Stacy 2004) or, potentially, Arapaho. Clark’s system also fails to account for those systems that combine free tone with stress-accent. A discussion of an example of a system that combines contrastive tones with stress is provided in Remijsen (2002, 2003). The language in point is an Austronesian language Ma’ya which “features lexically contrastive stress in addition to the three-toneme tone system”

(Remijsen 2003, 29). In this language stress and tone are marked with different acoustic means: the tonal contrast is encoded by changes in fundamental frequency, while stress is encoded by duration and vowel quality.

Phonetically, pitch-accent is essentially modulation of fundamental frequency. It has been claimed that cues that can possibly correlate with the pitch-accent are: “pitch (F0), energy and duration” (Rosenberg et al. 2009, 2)⁸.

3.4 Issues with the Existing Typology

Several issues seem to be crucial in the modern typology of prosodic systems of the world. As I have mentioned, it is often hard to draw clear lines between stress, tone, and pitch-accent systems. A good example of ambiguity of typological criteria in assigning languages to different word-prosodic types can be provided by the literature on prominence in the Blackfoot language. This Algonquian language has been claimed alternatively to have a stress system (Taylor 1969), a pitch-accent system (Kaneko 1999, Van der Mark 2001, 2003), and, finally, a tone system (Stacy 2004). B. Remijsen notes: “From the clear-cut distinctions of the [traditional] typology, new data are leading to a considerably less restricted word-prosodic typology”. (Remijsen 2003, 29). In this section, I will discuss the issues that arise when we try to delimit (1) pitch-accent systems from stress systems; (2) pitch-accent systems from tone systems; (3) stress systems from tone systems.

3.4.1 Pitch-accent vs. Stress

It is true that “the distinction between so-called “stress-accent” languages and so-called “pitch-accent” languages has never been very clearly defined. (...) So-called “stress-accent”

⁸ Perhaps, the spectral quality of the vowel should be added to these cues, and the empirical analysis presented in Chapter 4 of the current thesis takes this variable into account.

languages like English are generally contrasted with “pitch-accent” languages, of which the most well-known example is Japanese⁹” (Cruttenden 1997, 10). Pure stress systems and unambiguous pitch-accent systems display multiple similarities in their structure and functioning. Considering those similarities, L. Hyman proposed to make the distinction between *stress-accent* languages and *pitch-accent* languages (Hyman 1977). This approach suggests that *accent* is a generalizing notion which has to be further specified by the *cues of accent* employed in a specific language. This account of stress and accent was followed by M. Beckman in her book “Stress and Non-stress accent” (Beckman 1986). Modern scholarship on that issue seems to largely deploy this approach: “Within the category of lexical accent, it is useful to make a further distinction between lexical pitch-accent and lexical stress” (Remijsen 2003, 29). H. van der Hulst also accounts for pitch-accent as for one of the cases of a broader phenomenon of *accent*: “In a *pitch-accent* language, the accent is cued by a pitch property (an elevated pitch or a pitch rise, typically). In a *stress-accent* language, the manifestation is “stress” (Van der Hulst 2010, 480). Stress is cued by “properties that are typically associated with “stress” in languages such as English (extra-duration, extra-loudness, hyper-articulation etc.)” (Van der Hulst *ibid.*). Although this approach accounts for the existing commonalities between the two kinds of systems, it does not always help in separating them.

Obligatoriness and Culminativity of stress

I have mentioned that the core phonological criteria that describe a stress system are the principles of *Obligatoriness and Culminativity*. The notion of culmninativity and obligatoriness as

⁹ Interestingly, lately, it has been claimed that Turkish should also be analyzed as pitch-accent language (see Kamali 2010 for the analysis). I. Vogel notes: “Given the particular subtlety or absence of stress cues in Turkish, it appears that Turkish may have undergone, or is currently undergoing, a loss of stress as a lexical phonological property” (Vogel et al 36, unpublished).

the major features of the word stress comes from the works of N.S. Trubetzkoy (Trubetzkoy 1960, 250). The more recent works on stress and accent systems typology still refer to these principles as to “basic” (e.g. Hyman 2006, Stacy 2004). These principles suggest that a word in a stress system must have at least one syllable marked with the primary stress, and at most one syllable marked with the primary stress. “In all of the stress systems, stress is an obligatory characteristic of a word” (Bondarko et al. 2004, 122); “Metrical structures have one designated terminal unit, the head of the word, which counts as the (primary) ‘stress’” (Van der Hulst 2011, 17). These principles are usually used to claim that systems like that one of Arapaho cannot be assigned to the group of stress languages, because it is not unusual for words in this system to have several prominent peaks. However, I would like to argue that modern data and experimental research on the prototypical stress languages show that neither culminativity nor obligatoriness can be very reliable when assigning a language to one or another prosodic type. That is, in the “prototypical” stress languages, depending on the phonetic and phonological phrasal environment, and sometimes even in isolation, some words can be pronounced with more than one syllable marked with primary stress, or with no stress at all. E. Arkhipova gives examples of multi-stressed words in Russian (Arkhipova 2002, 86):

(5)

[tɕɪ tʲi' rʲohi' tɕɹnʲi] four-storied
 ['gʲɪdrəθ' lɛktrə' stantɕɨjə] hydroelectric power station

Arkhipova's experimental study showed that a Russian word can have several equally prominent syllables in terms of cues of stress, such as duration, amplitude and spectral quality.

It was also noted that in Russian speech the intervals between stresses are likely to be no more than 3 syllables; longer words get marked with additional stresses that can be just as strong (in terms of cues of stress such as vowel quality, duration, and pitch) as the “vocabulary” primary

stress (Kochnev 1992). On the other hand, H. van der Hulst mentions that “an issue that goes to the heart of what is often seen as problematic for the notion of ‘pitch-accent’ is that languages which allegedly have a pitch-accent system, and thus accent, sometimes have (lexical) words that appear to be unaccented” (Van der Hulst 2011, 17). It appears to be true not only for the pitch-accent systems, but for the “pure” stress systems as well. It’s been experimentally proven that depending on the phrasal position and prosodic environment, Russian words can be pronounced with no stress at all (Bogomolets 2011, 146):

(6)
[ʂɪstʲ-kərə'blʲɛj] **six** ships
[səʒlʲɛsnə-pri'ɪ'danʲɪəm] **according** to legends¹⁰

For English, it’s been noted that some types of words most commonly occur in an unstressed form in connected speech, e.g. “the articles typically occur without a stress and with a reduced vowel. Other types of words most commonly occurring without a stress (and with reduced vowels) are auxiliary verbs, personal pronouns and shorter prepositions and conjunctions” (Cruttenden 1997, 17)¹¹.

The second issue that arises when we try to apply the criteria of obligatoriness and culminativity to some unclear prosodic systems, like that one of Arapaho, is the issue of differences in what we call a word in different languages. A “normal” word can be so drastically

¹⁰ Cases like these are conveniently described by the notion of *phonological word* (or *prosodic word*, or *clitic group*). *Phonological word* is a phonological constituent that can be composed of one stressed unit (clitic host) and one or several unstressed units (clitics) (e.g. Zlatoustova 1981, Kalenchuk et al. 1993, Hall 1999, Kasevitch et al. 2008, Vogel 2009 among others).

¹¹ L. M. Hyman points out that “many stress languages are described as having at least some words lacking stress, e.g. Kitsai, Saho and Seneca” (Hyman 1977b, 38). He mentions that in the case of those languages “stresslessness is of greater significance” than in the languages in which only some clitics can lack stress. Moreover, in the Saho language “unstressed words are somewhat more common than stressed words” (*ibid.*).

different from language to language that trying to apply the same criteria seems pointless. The principle of culminativity is much easier to apply to the languages like English or Russian, where a normal word rarely exceeds 4 syllables. However, we have a completely different situation in languages like Arapaho. In this language, it is not unusual for a word to consist of 8, 9, 12 syllables. In fact, such a word would be translated into English with a whole phrase:

(7)
né'ni'h'iisiixoo'hóó3ihéénoo
né' -nih -'iisi -ixoo'hóó3ih -ée -noo
back Past how teach (TA) middleV 1Sg
That was how I was taught

In such cases it seems natural that a language allows for several prominent peaks within a word¹². It definitely violates the principle of culminativity, but in this case culminativity does not look like a “basic” or a “core” criterion for labeling a language as a stress or a pitch-accent system. H. van der Hulst has “suggested that accentual systems should be ‘allowed’ to have unaccented words or multiply accented words, or even both. This seems to imply that obligatoriness and culminativity are not necessary properties of accent” (Van der Hulst 2011, 16). Perhaps, a different way of accounting for the issue of culminativity in the languages of the world would be to talk about a scale of culminativity, rather than an absolute property of culminativity. One way of accounting for the differences in constraints on the number of accents per word would be to account for the types and origins (lexical, postlexical, rhythmical etc.) of non-culminativity:

¹² Cf. Stacy (2004) where the author argues for the Blackfoot language to be reanalyzed as a tone system, instead of pitch accent system: “...phonetically, pitch acts as the acoustic correlate; phonologically, Blackfoot exhibits accentual violations and irregular edge-effects – including severe breaches of culminativity, with cases of up to four accents per word” (Stacy 2004, 2).

Prominence

culminative accent

predictable rigid hierarchy

of prominence in a word

(???)

Prominence

metrical violations of culminativity →

phrasally-predictable distribution

of prominent peaks in a word

(English, Russian)

Semi-Prominence

lexicalized violations of culminativity

distribution of accents depends on →

morpho-lexical properties of a word

(Arapaho, Blackfoot)

Non-prominence

each syllable (morpheme) marked for tone

distribution of tones is lexically-predictable

(Mandarin Chinese)

To my knowledge, this possibility has never been discussed in the literature, since culminativity is usually considered to be a binary feature in stress-accent languages.

At the same time, it's been claimed that some tonal systems can employ the principle of obligatoriness. "In many languages, low-toned words (or some domain) are not allowed" (Cahill 2008, 6-7). This observation suggests that the tendency of having prosodic and metrical variation is somehow preferable for any kind of prosodic system. "A possible explanation for this lack of all-low tones in a word is that communication of any sort requires variation in the signal. A totally flat pitch is less communicative than one which exhibits such variation" (Cahill *ibid.*). This observation one more time confirms that obligatoriness cannot be a characteristic and distinctive feature of stress systems.

Hierarchical character of stress

Another characteristic that is usually claimed to distinguish between stress and pitch-accent is the hierarchical nature of stress. After culminativity, hierarchical character of stress (also called *metricality*) is commonly thought to be the “second fundamental property of stress systems” (Stacy 2004, 28). Prominent syllables are thought to create a hierarchy within words, phonological words, phrases etc. Such a metrical hierarchy is closely related to the degrees of reduction of unaccented vowels, and to the intensity of the cues of prominence in different syllables. “Working in tandem with culminativity, this property creates one prominence per accentual unit by relegating any stress besides the primary one to a ‘secondary’ position” (Stacy, *ibid.*). However, this principle is not even nearly universal. It seems to hold true for the systems with free stress, i.e. systems in which stress is not always associated with the same position in a word but can take virtually any position. For instance, Russian stress has long been claimed to be organized hierarchically: “Each word in the Russian language can function in one of the three scenarios: when we pronounce it out of a context, the stress is easily defined; in a phrase the word can occur in the strong accentual position, then the prominence of the stressed syllable will be on its maximum; or it can occur in a weak accentual position, then the prominence of the stress might happen to be insufficient for the syllable to be recognized as stressed” (Bondarko 1998, 228). There hasn’t been enough study on the issue of prominence hierarchy in the pitch-accent systems. However, even in the prototypical stress systems this principle does not always work: “In most languages it is not necessary or even possible, to distinguish between different degrees of stress/accent. In French, for example, the final syllable of a word-group is accented and non-final syllables in a word-group are generally unaccented. No analyses of French

distinguish two intermediate levels of stress/accent; at most some analyses distinguish one intermediate level, often called an ‘accent d’insistance’, indicated by high pitch and/or extra length and loudness” (Cruttenden 1997, 19). This observation then suggests that hierarchical nature of stress cannot be a reliable criterion for distinguishing between stress and pitch-accent systems either.

Phonetic cues of stress and pitch-accent

Most of the existing works on stress and pitch-accent suggest that stress systems differ from the pitch-accent systems in the way in which prominence is cued. Pitch-accent systems usually only employ fundamental frequency to cue the prominence. Tokyo Japanese is traditionally taken as an example of such “prototypical” pitch-accent system, where the prominent syllable has higher pitch than the syllables around it (Beckman 1986, Haraguchi 1988, Hyman 2001). Stress systems mark prominence with multiple features such as duration, spectral quality, fundamental frequency, intensity. However, it’s been reported that in the Blackfoot language, pitch-accent is cued not only by modulation of fundamental frequency, but also by intensity of the accented vowel. “The results of the analysis suggest that F0 peak and average amplitude are both correlated with prominence in Modern Blackfoot, while duration, amplitude peak and total amplitude are not. That is, pitch and loudness over the whole syllable are deliberately manipulated as markers of word prominence by Blackfoot speakers” (Van der Mark 2002, 205-206). Perhaps, “...on closer investigation so-called pitch-accent languages also involve additional phonetic cues such as duration, but to a much lesser extent than English” (Van der Hulst 2010, 12). Another question is whether there are pure stress languages (phonologically) that employ only one type of acoustic correlates, for instance, duration, or spectral quality. In this case we would be able to talk about duration-accent systems, or quality-accent systems.

3.4.2 Pitch-accent vs. Tone

It can be hard to distinguish between pitch-accent and tone systems because both employ the same physical cue – modulation of fundamental frequency. Therefore, the differences between the two kinds of systems should lie in phonology rather than in phonetic properties. From the *phonological point of view*, tonal systems require tonal contrasts on every syllable of a word. The main *function* of tonal contrasts is distinctive; tonal oppositions distinguish meanings. “The grammatical unit with which this function is associated is the minimal unit for which the meaning can be distinguished – the morpheme” (Beckman 1986, 26). Pitch-accent, on the other hand, is not distinctive, it rarely distinguishes lexical meanings and it is not required on every syllable of a word. Pitch-accent has “as [its] primary function the production of culminative patterns that phonologically conjoin closely cohering combinations of morphemes and set up larger sense groups in an utterance. The smallest grammatical unit with which this function is associated is therefore a unit usually larger than the morpheme, a minimal unit for which an accentual pattern can be specified – the word” (Beckman 1986, 26). E. Pike drew the line between “multiple stress systems” (pitch-accent systems in our terminology) and tone languages in the following manner: “I would say that a high pitch as a contrastive feature of stress affects its environment, whereas a high pitch as a contrastive feature of a tone system is affected by its environment” (Pike 1974, 169). In fact, it was claimed that “pitch-accent languages must satisfy the criterion of having invariant tonal contours on accented syllables, since tone is a lexical property” (Hayes, 1995, 50). Pitch-accent, as well as stress in prototypical stress languages, can shift due to morphological reasons. Although it would still be a lexical property, a shift of accent or stress produces a new morphological form or sometimes a new lexeme. In this regard, pitch-accent might function very similar to stress-accent. Compare examples below:

(7)

Russian

Bég – run (N.)

Vy**beg**átj – to run out (V., Infinit., Imperf.)

Vý**bez**hatj – to run out (V., Infinit., Perf.)

Begú – I am running (V., Pres., Imperf.)

Russian example shows how stress shifts depending on the morphological affixes added to the stem “beg” (*run*). The following Arapaho example illustrates essentially the same mechanism – the shift in accent accompanies morphological changes:

(8)

Arapaho

Béxo – sticks, pieces of wood (N., pl.)

niise’í**bese**enoo – I go and get wood; I produce lumber (V., Pres., Imperf.)

Héétwon**besé**eenoo – I will go get the wood (V., Fut., Imperf.)

The major difference between tone and pitch-accent systems can be described in terms of syntagmatic vs. paradigmatic relations. Accent is syntagmatic since it “locate[s] an entity within a given syntagm (or horizontal stretch)” (Hyman 1977, 3). Accent involves syntagmatic contrasts, and that “separates accent from paradigmatic prosodic contrasts, such as the opposition between long and short vowels in Japanese or the opposition between high-level syllables and high-rising syllables in Mandarin Chinese” (Beckman 1986, 1)¹³. Tonal properties in tonal

¹³ At the same time, interestingly enough, systems like Russian are sometimes referred to as *paradigmatic accent systems* (see Dybo 1981, 1989). It has been noted that “(a) in simple roots [in paradigmatic accent systems] the position of the accent can be quite arbitrary (not depending on the form or meaning of the root) and is explained only as an inherent lexical feature, and (b) in derivatives the position of the accent may be determined by the accent types of the constituent morphemes” (Pejros 1994, 106). In such systems derivatives of the same root can have different accent placements (see examples (7) and (8) of the current paragraph).

languages “can be seen as performing part of the vowels, just like their other properties (open vs. closed jaw, front vs. back raising of the tongue, rounded lips vs. spread, and others)” (Van der Hulst 2010, 12). In tonal languages, in contrast to pitch-accent languages, tone does not make one syllable more prominent than another. The difference in functions of tonal and pitch-accent systems correlates with the number of contrastive tones. Pitch-accent systems usually have no more than two tonal possibilities: H and L, or H and no-tone, whereas tonal systems tend to have three or more contrastive tone heights.

3.4.3 Stress vs. Tone

The stress-tone distinction seems to be the least problematic one, since both, phonetics and phonology of the two types of systems are quite different. Most of the phonological features that differentiate pitch-accent systems from tone systems can as well be applied to differentiating between stress-accent and tone systems.

From the *phonological stand*, stress and tone differ in function, in the unit with which prominence is associated, and in the degree of relativity of prominence. The main function associated with stress is a metrical or organizational function. “Stress is a structural feature that is derived from relationships among many different content features” (Beckman et al. 1994, 9). The main function of tone is contrasting lexical items. This means that tone is a paradigmatic specification. Stress is syntagmatical, relative, while tone is paradigmatic: “Restrictions in stress patterns are determined syntagmatically: (a) stress is relational because the particular degree of stress in a syllable depends on the relative stresses of adjacent syllables; and (b) stress is culminative because the differences in prominence between syllables result in a higher degree of stress in a particular position. The interpretation of tone height is possible without referring to tones in adjacent syllables” (Rivera-Castillo 2004, 264). Metrical Theory of stress also accounted

for the difference between syntagmatic stress and paradigmatic tone: “the stress-bearing elements are mere positions, identified by their sequential order counted from right to left or from left to right. In that respect, stress crucially differs from tone, which is associated with units identified by their phonetic substance which partakes of this phonetic substance” (Halle, Vergnaud 1983, 6).

From the point of view of *phonetics*, stress systems are quite different from tone systems in the cues that they employ to mark prominence. As I have mentioned above, stress systems usually cue prominence with a combination of acoustic features such as duration, intensity, spectral quality, fundamental frequency. The only phonetic feature employed in the tone systems is modulation of fundamental frequency.

3.5 Brief Conclusions

Drawing lines between different prosodic systems is puzzling. It gets especially challenging when we try to assign unclear, mixed, non-prototypical systems to one or another prosodic type. The challenge of this task lies partially in imperfection of the prosodic typology, and partially in the great diversity of prosodic features and their combinations that we find in the languages of the world. In the “Issues” section, I attempted to show that some notions that are thought of as the basis for the distinction between the types of prosodic systems simply do not work, like the notions of obligatoriness and culminativity of stress. Some others do not always apply (like hierarchical character of stress), and therefore cannot be reliable when we try to assign a system to one or another prosodic type. Yet another problem arises when we acknowledge that some systems simply employ none of the three traditional word-prosodic features. “French, Indonesian, and possibly Tamil fall in this category. These languages have no

lexical stress, lexical pitch-accent, or lexical tone” (Remijsen 2003, 29)¹⁴. L. Hyman reported that 16 languages in his study of 444 languages displayed no stress-accent and no tone (Hyman 1977b, 56).

I would also like to mention two general issues that arise while working with different prosodic types. The first one is vagueness and uncertainty of what we call a word in different languages (see Dixon and Aikhenvald 2002 for a detailed discussion). Being used cross-linguistically, this notion is crucial for prosodic typology. However, the comparison of prosodic features of an Arapaho word to those ones of an English word, for example, is pointless simply because the units referred to as “words” in those languages are drastically different. Comparison of an Arapaho word to a word in Mandarin Chinese, on the other hand, also seems fruitless. I have mentioned that pitch in Arapaho does not function in the same way as in Mandarin, since it is rarely (if ever) used to distinguish between lexical items. Making such a claim we need to remember that the number of homophonous monosyllables in Mandarin is not comparable to the number of homophones in Arapaho because the chance of homophones in Arapaho is minimized by its polysynthetic nature.

The second general issue concerns the procedures of doing any typological research of an under-described language. Well-described and thoroughly studied languages are usually assigned a place in the typology based on the language features, while the under-described languages are

¹⁴ Gordon notes: “Perhaps the most striking case of a language that has frequently been analyzed as having word-level stress but has been experimentally shown to possess only boundary pitch excursions is Indonesian. Many accounts of Indonesian posit stress on the penultimate syllable of a word with, in some analyses, a provision that schwa in the penult relinquishes stress to the final syllable (see van Zanten and van Heuven 1998 for an overview). Van Zanten and van Heuven (1998) show, however, that Indonesian listeners fare no better in word recognition gating experiments when presented with a stressed syllable than when hearing an unstressed syllable. Based on this result, they conclude that stress plays no essential communicative function for Indonesian speakers” (Gordon unpublished, 4).

usually classified based on the features of speech. The consequences of employing these two different approaches become obvious when the analysis of spoken data in the well-described languages confronts the existing typological criteria, the presupposed idea of what the features of this well-known language should look like. I provided an example of such a mismatch in the “Stress vs. Pitch-accent” section of this chapter. Existing typology tends to compare language features of some languages to the speech features of the others.

For a long time it has been believed that “the classification of a language’s suprasegmental system requires that its features match a subset of typological characteristics for pitch-accent, tonal, or/and stress languages” (Rivera-Castillo 2004, 263). However, it is obvious that the prototypes themselves and fitting languages in the frames of those prototypes are always more or less arbitrary (Hyman 1978 and 1992). As Mary E. Beckman noticed, perhaps “a more appropriate view is to set up a continuum between “pure” accent and “pure” tone, locating [suprasegmental] phenomena in various languages along the continuum” by the relative salience of multiple phonetic and phonological features (Beckman 1986, 2). Finally, recent studies on word-prosodic systems report multiple patterns that cannot be adequately accounted for with the means of existing typology. Acknowledgement of an amazing diversity of suprasegmental systems possible in languages of the world and detailed phonetic descriptions of under-studied languages will eventually help us to arrive at a new understanding of word-prosodic typology.

Chapter 4. Pitch-Accent and Arapaho

In this chapter, after giving a brief overview of existing scholarship on phonetics and phonology of Arapaho prominence, I proceed to the discussion of methods and results of experimental study of acoustic correlates of accent in Arapaho. At this point, I present raw data derived from investigation of four variables – fundamental frequency, duration, intensity, and spectral quality of the vowels. In Chapter 5 of the current paper, the primary data presented in this chapter will be subjected to statistical analysis in order to verify statistical significance of the results.

4.1 Arapaho Prominence

It was noted that ‘pitch-accent [in Arapaho] has resisted attempts at explanation up to the present’ (Cowell 2008, 80). Indeed, to date, there is no comprehensive research on phonetics and phonology of the accent system in Arapaho.

It is traditionally claimed that just like tonal systems (e.g. Mandarin Chinese), Arapaho uses pitch (i.e. modulation of F0) as the main cue of prominence. Unlike the “pure” tonal systems, Arapaho uses pitch non-distinctively (see Salzmann 1998, Cowell 2008). The distinctive use of pitch presupposes two things: (1) each morpheme has to be marked for distinctive pitch; (2) pitch distinguishes different otherwise identical morphemes, therefore we should be able to find minimal pairs. Neither of these two principles works for Arapaho. Although we can find some minimal pairs, A. Cowell notices that “it is extremely difficult to find minimal pairs of nouns based on pitch-accent” (Cowell *ibid.*). At the same time, it is claimed that “pitch-accent is a morpheme-level phenomenon – the pitch is part of the underlying form of the morpheme” (Cowell *ibid.*), which normally occurs in tone systems.

Although accent in Arapaho is lexicalized, i.e. we are able to find the accent marks in dictionaries (e.g. Salzmänn 1983), “[native speakers] are not necessarily good at marking them [pitch-accents]” (Cowell *ibid.*). This observation is interesting for a couple of reasons. First, it might suggest that the Arapaho speakers do not store the accentual information together with the lexical information, i.e. accent in this language might be much more lexically independent than stress-accent in stress languages. Second, it might suggest that word-level accent is not (always) “default”, not stable in this language, that is, it gets assigned on the phrasal level. In this case, the main function of accent in Arapaho would probably be metrical. “Metricity” of pitch-accent in Arapaho seems to be supported by the fact that “word-level pitch-accent rules cause redistribution of the pitch-accents to avoid adjacent syllables with pitch-accents” (Cowell 2008, 85). On the other hand, it is necessary to remember that usually an “untrained subject is less aware of stress than of phonemic distinctions and it is difficult to evoke an operational response to stress differences” (Fry 1958, 130).

Any accent-bearing unit can bear accent in Arapaho, i.e. there are no restrictions on where accent can fall. “The pitch accent system [of Arapaho] involves underlying accent on morphemes, intermorphemic shift in pitch at the word level, and grammatical shifts in pitch accent related to inflectional forms such as plurals, locatives, iteratives, and participles” (Cowell 2008, 81). Perhaps, pitch-accent in Arapaho could be best described as *morpho-lexical*; it is a property of a word, but this property is dependent on morphological and morphemic information¹⁵.

Although there can be found very little information on the prominence in Arapaho, it is known that there are ‘two pitches, high or normal’ (Cowell *ibid.*). This suggests that there is only

¹⁵ L.M. Hyman refers to this as to *morphological* function of *grammatical stress* (Hyman 1977b, 39).

one *level tone* in Arapaho, therefore the opposition H-L that can be encountered in tonal languages is replaced by the opposition H-Ø¹⁶, which often happens in the pitch-accent systems (Van der Hulst 1988, 21). A. Cowell points out that one can find *falling contour tone* in Arapaho. Falling contour tone (high to normal) in Arapaho occurs only on long vowels and diphthongs. Contour tones in Arapaho can be of two phonologically different kinds.

- a) Falling tone is a secondary allophone conditioned by juxtaposition of a pitch-accented vowel and an accentless vowel:

(9)
 ˈV1V1
 Bebíis – proper

- b) Falling tone is a secondary allophone conditioned by the pitch-accent of surrounding syllables:

(10)
 ˈV1 ˈV2ˈV2 V3
 néi-**hòòw**-biicí3ei
 1S – NEG - beading
 I am not beading

In my unpublished research on the falling tone of the type b), I established the rules that govern distribution of this type of contour tone in Arapaho:

VV → VV / V ____ (V)
 [flat] [fall] [H] [flat]

The rule presented above states that this type of falling contour tone in Arapaho occurs on a syllable with underlyingly flat long vowel if this syllable is preceded by a pitch-accented syllable and (optionally) followed by an unaccented syllable.

It is also possible to state the neutralization rule:

¹⁶ That is, the tone system in Arapaho can be described in terms of privative opposition. A privative opposition is one in which one member is characterized by the presence of a feature, the other by the absence of the feature (Trubetzkoy 1976, 77).

VV -> VV / V __ V
 [fall] [flat] [H] [H]

This rule describes the environment of neutralization of the falling tone: falling tone is neutralized (goes to flat) if followed by a pitch-accented syllable:

(11)
 néí-**hoow**-óesówobéíh
 1S – NEG – sick
 I am not sick

That empirical research has also confirmed that there is no such thing as a rising contour tone in Arapaho.

Phonetic nature and features of pitch-accent in Arapaho have never been addressed in the literature. It's been noted however that "the relative prominence of the pitch-accent varies considerably both within and between words. As a rule of a thumb, initial pitch-accents have lowered prominence, as do some final pitch-accents on short vowels. Conversely, final non-pitch-accented syllables ending in a glottal stop tend to have increased prominence and can be difficult to distinguish from syllables with pitch-accent" (Cowell 2008, 90). There have been no experimental studies of the phonetic difference between accented and accentless syllables in Arapaho, but the common view on the accentual system in this language suggests that prominence is marked exclusively (or mainly) by modulation of fundamental frequency. The following sections of this chapter present the procedures and results of empirical research of the cues of accent in the Arapaho language.

4.2 Data

The data used for this study were elicited by Dr. Andrew Cowell from a male Arapaho speaker at the Phonetics Laboratory of the University of Colorado at Boulder as an addition to the Arapaho Database Project. The recordings were made with the omnidirectional microphone Earthworks M30. The total of 120 words (60 with accented target vowels and 60 with

unaccented target vowels in a specific neutral environment) were recorded in isolation. Each word was read twice. The words were arranged in random order. Filler items were added at the beginning and end of each page of the list. Recordings were analyzed in Praat (Boersma and Weenink 2010). All target stressed vowels, target unstressed vowels, and vowels in the syllables preceding the target accented vowels, amounting to 180 tokens, were hand-labeled in a TextGrid. Measurements were taken by script, using LPC formant tracking at the midpoint of vowels (with a maximum formant value set at 5000 Hz, and the number of formants set at 5). The script records the first through third formants; the maximum and mean F0; the maximum and mean amplitude; and the duration of the vowel. Formant tracking errors were corrected manually.

4.3 Experimental Procedures

While conducting an experimental study of acoustics, researchers have to admit that the results of the study always depend on the way in which the experiment is designed. S. Cassidy and J. Harrington notice that “in the large majority of studies in speech acoustics attempts are made to control as far as possible for many of the effects of variability” (Harrington, Cassidy 1999, 4). Controlling as many variables as possible is crucial if we aim to get objective and reliable analysis of phonetic features. To my knowledge, there are no clear rules for designing an experimental study of pitch-accent. I suggest that the following factors can possibly affect the pronunciation of a pitch-accented vowel.

- a) *The place of the target vowel (target syllable) in a word.* It seems relevant to control the place of the target vowel in a word in order to ensure a relatively similar phonotactic environment for all the vowels in the study. Target vowels (target syllables) in the present study are preceded and followed by an unaccented syllable in order to avoid any contour-like phenomena, e.g. *Héétwon**bé**nenoo* = *I will go drink*; *Hees**í**niinoo* = *I am*

injured. I also avoided analyzing initial and final syllables which tend to be marked cross-linguistically either with additional emphasis or with lenition.

- b) *The quality of the consonant that precedes the target vowel*. The properties of the syllable onset can influence the acoustic features of pitch-accent. For example, Lehiste and Pavle (1978, 103) argue that voicing of initial consonants affects the realization of the F0 curve in Serbo-Croatian. It's been reported that the quality of a consonant can determine a particular tonal pattern in Kanakuru (Chadic: Nigeria) (Odden 1995, 452): the HL pattern is encountered in verb stems beginning with a voiced stop; while the LH pattern occurs in those beginning with a voiceless stop (Odden 1995, 452). Kingston and Diehl (1994) claim that [...] "F0 is depressed next to [+voice] stops" (1994, 425). All these combinatory effects seem to be language-specific. In the current study, I avoided analyzing pitch-accented syllables that start with voiceless velar and glottal fricatives ([x] and [h]). Although there is no study of correlation between the quality of a consonant and pitch-accent in Arapaho, I observed that those consonants might cause pitch raising on the following vowel (Figure 2). Laryngealization of those consonants can be a possible explanation of this effect. The exact reasons of that phenomenon, although they would be very interesting to investigate, are out of the scope of the present study.

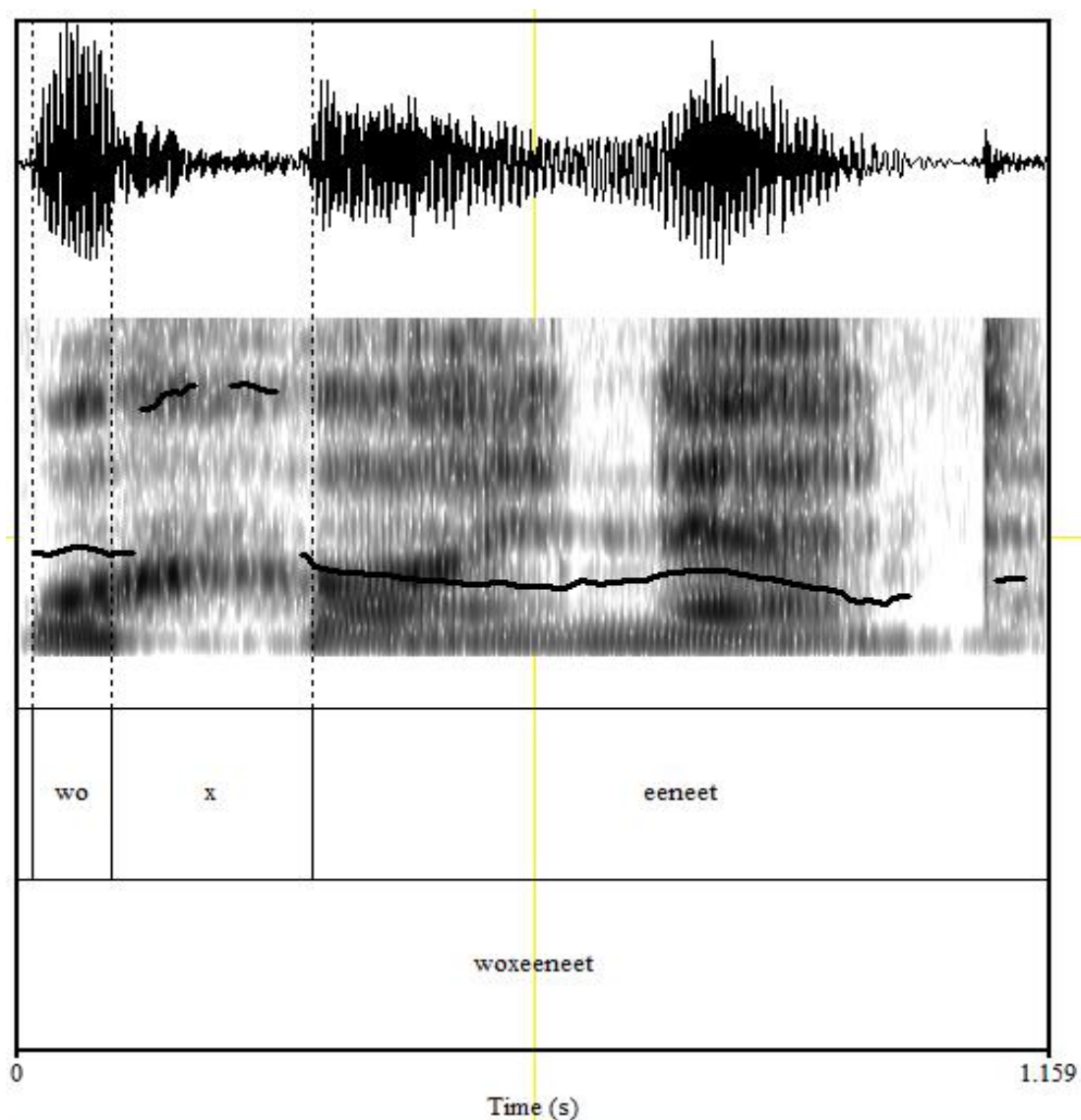


Figure 2. Laryngealized /x/ and associated with it high pitch contour

- c) Finally, *The identity of the target vowel*. While trying to establish the difference between accented and unaccented vowels, it seems reasonable to compare only corresponding vowels. In other words, I only compare ['ɔ:] (accented long open mid-back rounded vowel) to [ɔ:] (unaccented long open mid-back rounded vowel) etc. For example, vowels in the following words can be compared (in bold):

héétwonbénenoo = I will go drink	hécesbetee3óó = angel
<i>Target syllable is not initial and not final; Target syllable preceded and followed by an accentless syllable; Target vowel – accented /e/</i>	<i>Target syllable is not initial and not final; Target syllable preceded and followed by an accentless syllable; Target vowel – unaccented /e/</i>

Table 3. Accented-accentless counterparts for the comparison of acoustic features of accented /e/ vs. unaccented /e/

The present study assesses Arapaho prominence with six acoustic variables: pitch peak and mean pitch of the target vowel (F0, fundamental frequency), which are measured in Hertz (Hz); amplitude peak and mean amplitude throughout the vowel (in dB); duration (in ms), and spectral quality of the vowel (peripheral versus central, i.e. precision of articulation, F1, F2, F3).

4.4 Prominence and F0

Fundamental frequency is considered to be the main cue of prominence in pitch-accent languages. “Physiologically, pitch is primarily dependent on the rate of vibration of the vocal cords within larynx. (...) Rate of vibration of the vocal cords is reflected in the acoustic measurement of fundamental frequency. This term refers to the number of repetitions of the regular waveform within one second, such a regular waveform being typically produced when the vocal cords vibrate for voicing” (Cruttenden 1992, 3). The procedures of measuring pitch are not straightforward. Previous studies have employed different methods. Rivera-Castillo et al. report that “in a study of downdrift in English intonation, Nolan (1995) measured F0 at the durational midpoint of each accented vowel. In a study of the phonetic interpretation of tone in Igbo, Liberman, Schultz, Hong, and Okeke (1993) measured the maximum value for H tones and the minimum value for L tones wherever these values appeared in the nucleus” (Rivera-Castillo et al. 2004, 271). I. Vogel in her study of correlates of prominence in four different languages

measured F0 “in two ways: the mean F0 of the entire target vowel and the means of four portions of the vowel (i.e. from the beginning to 25%, 25% to 50%, etc.)” (Vogel et al., unpublished, 15).

Fundamental frequency of a vowel, of course, is not completely independent of the environmental properties. The F0 measurements may be affected by a number of factors such as perturbations of pitch connected to the preceding consonant, the effect of utterance-level intonation, and other postlexical effects (see Beckman 1986 for a detailed discussion). It has been noticed that pitch features “have a particularly close relation, synchronically and diachronically, with features which are controlled primarily at the larynx, e.g. voicing, aspiration, glottalization, length, breathiness etc.” (Wang 1967, 94). The data for the current experiment were collected in a way that would minimize the postlexical effects. A. Cruttenden pointed out that “whether or not consonants are voiced affects the fundamental frequency of adjacent voiced sounds” (Cruttenden 1992, 4). Vowels tend to have a higher fundamental frequency when preceded by voiceless consonants than when preceded by voiced consonants. Moreover, the fundamental frequency peak will be at the beginning of the vowel following voiceless consonants but in the middle of the vowel following voiced consonants. Stacy notes that “those researching Asian languages typically report that /ʔ/ leads to high tone on preceding vowel” (Stacy 2001, 122).

For the current study, I measured pitch peak and mean pitch for every target vowel (60 accented and 60 unaccented vowels). The measurement of mean pitch seems to be reasonable since I have noticed that an accented vowel does not necessarily have a peak, sometimes it has a steady higher pitch instead.

Taking into account that “different types of vowels have inherently higher and lower fundamental frequencies: all other things being equal, open vowels will tend to have a lower fundamental frequency than close vowels” (Cruttenden 1992, 4), I compared the fundamental frequency measurements of corresponding accented and unaccented vowels (Tables 4 and 5).

	i	í	e	é	u	ú	o	ó
mean F0 peak	154.55	165.76	133.53	137.03	149.65	152.42	138.44	131.05
mean F0	134.61	153.55	114.45	129.86	131.87	140.49	125.74	124.5

Table 4. Mean F0 of short accented and accentless vowels

	ii	íí	ee	ée	uu	úú	oo	óó
mean F0 peak	137.64	132.45	140.17	128.71	147.94	142.46	123.86	135.31
mean F0	127.07	121.58	122.24	118.2	125.23	118.27	117.91	121.17

Table 5. Mean F0 of long accented and accentless vowels

Data presented in Tables 4 and 5 are rather unexpected for a language that has long been claimed to be a pitch-accent language. Short accented vowels indeed tend to have slightly higher fundamental frequency. Data in Table 5 show that long accented vowels, contrary to all predictions, tend to have lower pitch than long accentless vowels.

4.5 Prominence and duration

A lot of prosodic systems of the world exhibit correlation between prominence and duration. According to Lehiste and Pavle (1978, 102) accented syllables are longer than unaccented ones in a proportion of 3:2 in many stress-accent languages. In stress-accent systems, unaccented vowels are subject to quantity reduction – their duration is significantly shortened

which can lead to partial or full deletion of an unaccented vowel¹⁷. On the other hand, for the systems that employ pitch or tone differences, “low-toned vowels tend to be longer than high-toned ones” (Cahill 2008, p.3), and even “perhaps it is a universal that in a tone language a high tone is never longer than a low tone, when they occur in analogous environments” (Pike 1974, 170). It is interesting to test which of the two tendencies would be relevant for the pitch-accent system, since it might display features of both tone and stress systems¹⁸.

The duration measurement is the time in ms of the vowel. Duration measurements were made on the broadband spectrogram. Vowel-segment duration was defined:

- as the interval between the plosion of the preceding stop and the initiation of the occlusion of the following stop in the sequences *stop-V-stop*;
- as the interval between the end of the nasal murmur and the occlusion of the following stop in sequences *nasal-V-stop*;
- as the interval between the last burst of static noise of a preceding fricative and the occlusion of the following stop in sequences *fricative-V-stop*.

¹⁷ Halle and Vergnaud notice that the “widely held belief that stressed vowels are immune – or at least peculiarly resistant – to deletion” is not supported by empirical data in a wide variety of languages. They give an example of Russian noun *zajom* “loan”, in which the *o* in the stem is deleted if the following syllable contains a full vowel: *Zajom* nom., acc; *Zajma* gen; *Zajmu* dat. (Halle, Vergnaud 1983, 28-29).

¹⁸ This conflict between the tendencies in duration patterns is often overlooked in the studies of pitch accent systems. For example, Van Der Mark in her research on acoustics of Blackfoot prominence notices that the “pattern in duration is not clear”, because “the prominent syllable is shorter” (Van Der Mark 2001, 191). She concludes that “duration is probably not a correlate of Blackfoot prominence” (*ibid.* 193), when in fact there is a very clear pattern: duration of the vowels follows the tone languages tendency, i.e. high-pitch vowels are shorter than low-pitch ones.

In general, duration measurements did not pose any problems. The highlighted portion in Figure 3 indicates the vowel interval.

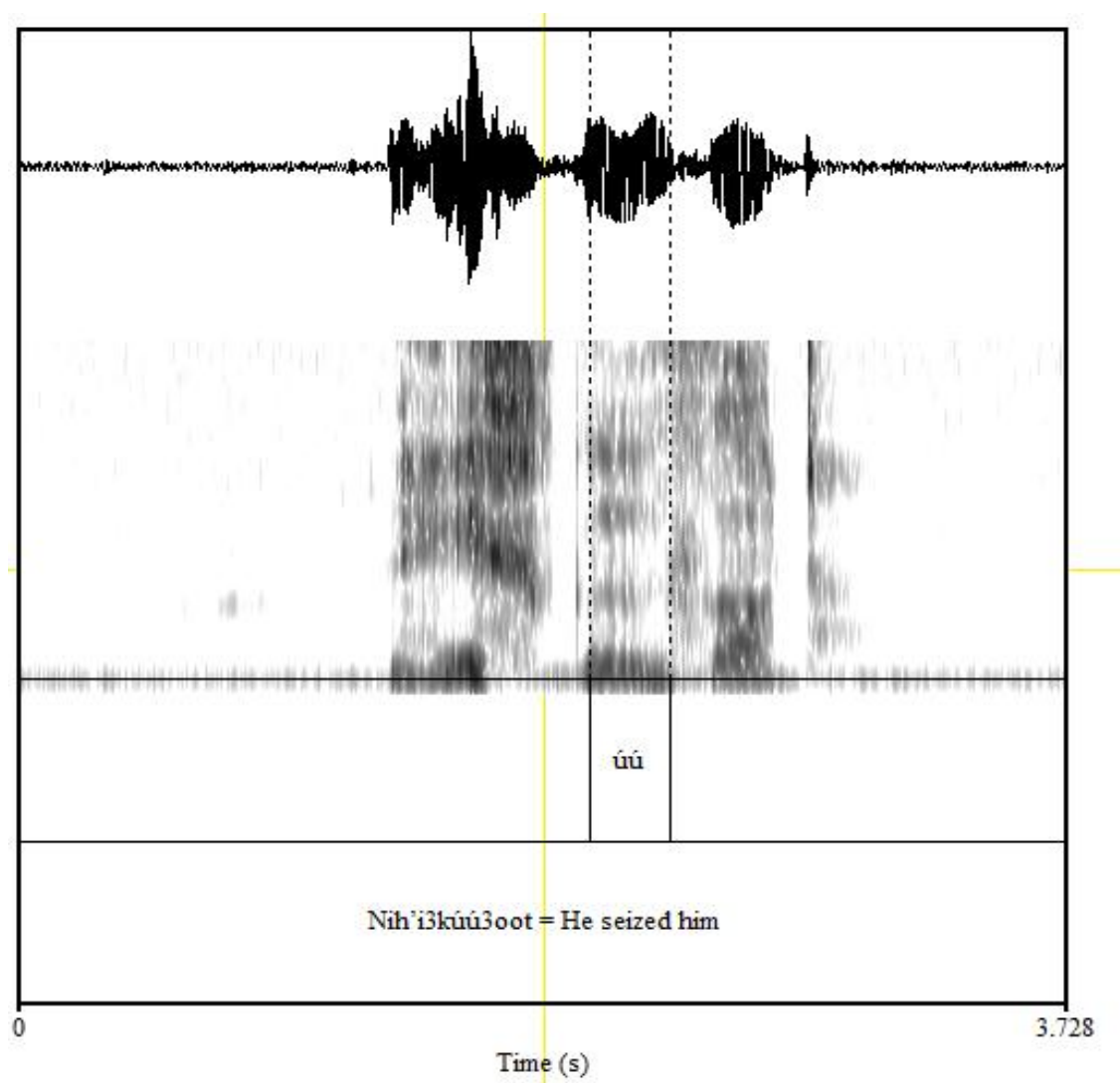


Figure 3. Vowel interval for duration measurements

The Arapaho language distinguishes between long and short vowels. Duration of short accented vowels was compared to duration of short unaccented vowels (Table 6), and duration of long accented vowels was compared to duration of long unaccented vowels (Table 7).

	i	í	e	é	u	ú	o	ó
mean duration (ms)	91.378	91	89.324	109.77	88.741	88.223	99.954	92.063

Table 6. Mean duration of short accented and accentless vowels

The data presented in Table 6 suggest that duration is probably not a correlate of prominence for short vowels in Arapaho. There is no clear pattern in Table 6. The accented vowel can be shorter than the accentless counterpart, it can be longer than the accentless variant, and the two can exhibit no significant difference in duration.

	ii	íí	ee	ée	uu	úú	oo	óó
mean duration (ms)	212.21	260.19	214.91	234.66	217.81	237.63	211.65	263.59

Table 7. Mean duration of long accented and accentless vowels

Data in Table 7 show that there is a clear pattern in duration between accented and accentless long vowels. Accented long vowels are constantly longer than accentless long vowels. Once again, just like with fundamental frequency, long and short vowels exhibit different patterns. Data presented in section 4.4 of this chapter showed that phonemic short vowels tend to have higher fundamental frequency when accented, while phonemic long vowels do not seem to employ higher pitch as cue of prominence. On the other hand, phonemic long vowels are consistently longer when accented, while phonemic short vowels do not exhibit any clear pattern in regard to duration as a cue of prominence. *These two tendencies seem to suggest that prominence is cued with higher pitch in short vowels and with longer duration in long vowels.*

Such an assumption seems rather surprising yet plausible. Duration simply can't be a reliable cue of prominence for short vowels because lengthening of the short vowels would create ambiguity in a language with contrastive length. Lengthening of phonemically long vowels does not lead to any confusion. Berinstein (1979) proposed that duration will not be an important cue of stress in a language with length contrast. That is, if in a language there is a high functional load of duration for the long/short phonemic distinction, duration will not be used to cue accent. Her hypothesis was supported by her study of three languages – English, K'ekchi, and Cakchiquel. I. Vogel's cross-linguistic research has also shown that "In languages with word level prominence (stress), the strongest correlate/s of this type of prominence will be distinct from the properties involved in lexical (phonemic) contrasts of the language" (Vogel et al. unpublished, 9). Among other observations, Vogel shows that "since Hungarian makes use of duration for contrastive vowel (and consonant) length, we do not find noticeable duration differences corresponding to either stress or focus (Vogel et al. unpublished, 26). My data seem to refine these findings if it is true that duration can be used as a cue of prominence in a language with phonemic length contrast if it does not create functional ambiguity.

The following two sections describe the patterns of acoustic variables that are traditionally considered to be "lower" in the hierarchy of correlates of prominence – spectral quality and intensity.

4.6 Prominence and quality of the vowel

Existing phonetic descriptions of pitch-accent systems in the languages of the world often do not attempt to instrumentally investigate difference in spectral quality between accented and

unaccented vowels¹⁹. Quality reduction of unaccented vowels can potentially be a strong correlate of prominence (or indication of its absence)²⁰. It is well-established that quality reduction is a characteristic feature of languages with heavy stress, such as English or Russian. However, it is possible that spectral quality of a vowel also correlates with prominence in pitch-accent systems. In stress-accent systems, “the obscuration of quality varies along a continuum of stronger and weaker forms, the precise amount of reduction being related to the degree of stress placed on the vowel” (Lindblom 1963, 1773). In different languages, reduced vowels undergo either centralization or neutralization of contrast. K. Crosswhite points out that the term *vowel reduction* should only be applied to “categorical quality change that is conditioned by phonological categories such as stress and/or phonemic vowel length, but not by non-phonemic categories like speech tempo”, on the other hand, “the vowel undershoot results in gradient changes in pronunciation that *can* be sensitive to tempo” (Crosswhite 2001, 3). The difference between reduction and the vowel undershoot in this approach can be illustrated with the example of reduction in Russian, where “the appropriate vowel reductions are mandatory at all speech tempos” (Crosswhite 2001, 8). The two main types of vowel reduction – *neutralization* and *centralization* – are displayed in Russian and English respectively. In English, reduction has a centralizing effect both vertically and horizontally: all unstressed vowels are on the average shifted toward [ə]. E. Flemming and S. Johnson have shown that “the mid central vowel [ə] that can occur in unstressed word-final position (e.g. in *Rosa*), and high reduced vowels that occur in

¹⁹ E. Pike, however, has noted that “in a [multiple] stress system (*pitch accent system* – K. B.), vowel quality is frequently conditioned by distribution in stressed syllables versus non-stressed syllables (Pike 1974, 171).

²⁰ It is noteworthy, that depending on the relational position to a stressed vowel “some features of consonant quality, such as the strength of friction or aspiration and the sharpness of onset of the consonant sound may act in a similar way” as vowel quality reduction (Fry 1958, 128). The impact of stress on the consonant quality in the Arapaho language would be an interesting topic for a future investigation.

most other unstressed positions, and might be transcribed as [i]" (Fleming et al. 2007, 83) are the outcomes of the centralizing reduction in English. In Standard Russian quality reduction does not cause vowels to centralize; rather it causes neutralization of contrasts – “at least some subsets of the phonemic vowels become acoustically indistinguishable from one another” (Crosswhite 2001, 6). In both kinds of reduction systems different degrees of reduction occur depending on phonological environment. For instance, Russian has been claimed to have two reduction patterns depending on the place of the unstressed syllable in a word: “”extreme” vowel reduction [is] a case of neutralization caused by prominence-reduction targeting durationally-impooverished unstressed syllables, while the changes seen in “moderate” reduction can be ascribed to a second reduction phenomenon that targets unstressed syllables in general” (Crosswhite 2001, 53). These patterns are illustrated in Figures 4 and 5.²¹

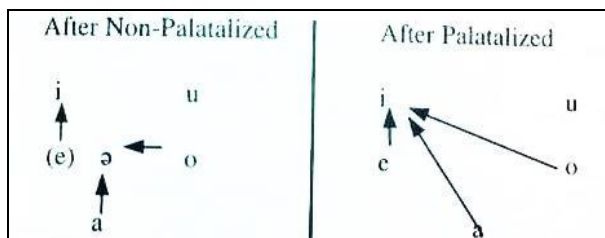


Figure 4. “Extreme” reduction patterns

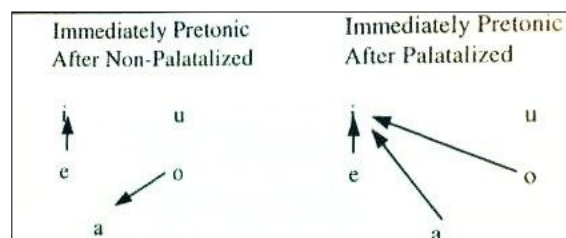


Figure 5. ”Moderate” reduction patterns

In order to investigate the relationship between accent and vowel quality in Arapaho, I measured formant frequencies ($F1$, $F2$, $F3$) for each target vowel in the data. These measurements can reveal the quality difference between accented and unaccented vowels in Arapaho, as well as show the nature of quality reduction if it exists, since we will be able to see whether the unaccented vowels undergo centralization or neutralization of phonemic contrasts.

²¹ Figures 4 and 5 are adapted from Crosswhite 2001, 61-63

Tables 8 and 9 show mean values of the first, second, and third formants for long and short accented and accentless vowels:

	i	í	e	É	u	ú	o	ó
mean F1	333.91	301.23	450.6	533.32	311.81	329.49	572.02	558.12
mean F2	2084.7	2001.4	1711.8	1504.8	1386.4	1256.8	1147.9	1081.2
mean F3	2912.6	2814.6	2768.9	2789	2757.6	2714.8	2876.1	2777.4

Table 8. Mean F1, F2, F3 for short accented and accentless vowels

	ii	íí	ee	éé	uu	úú	oo	óó
mean F1	289.79	265.94	498.25	492.62	308.41	322.21	579.81	570.16
mean F2	2297.3	2310.8	1850	1681.8	1214.6	1379.8	1292.7	982.95
mean F3	2880.8	2886	2737.7	2831.2	2696.9	2657.7	2997.3	2882.1

Table 9. Mean F1, F2, F3 for long accented and accentless vowels

Data in Tables 8 and 9 are plotted in the following Figure 6:

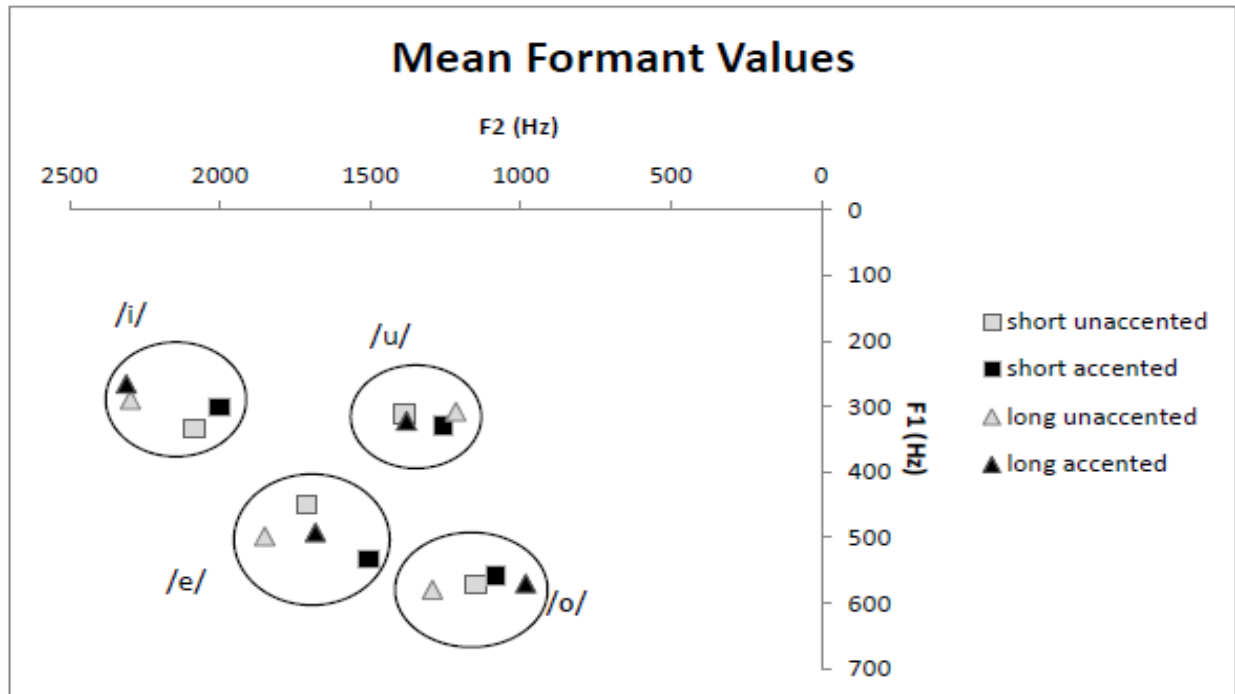


Figure 6. Formant qualities of accented and unaccented long and short vowels

The following scatter plots (Figures 7-10) illustrate the range of formant values for all phonemic vowels of the Arapaho language.

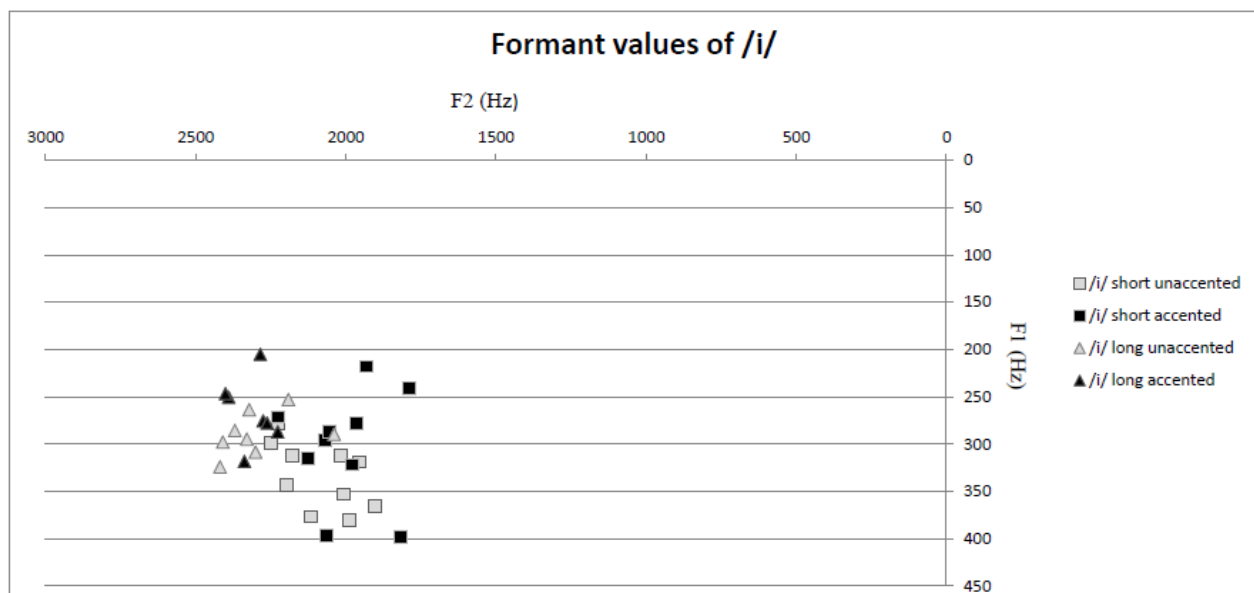


Figure 7. Formant values of accented and unaccented long and short /i/

The plot in Figure 7 shows that although there is not much variation in /i/ depending on the accent, long accented vowels are the most peripheral while short accented and unaccented variants of /i/ are more central.

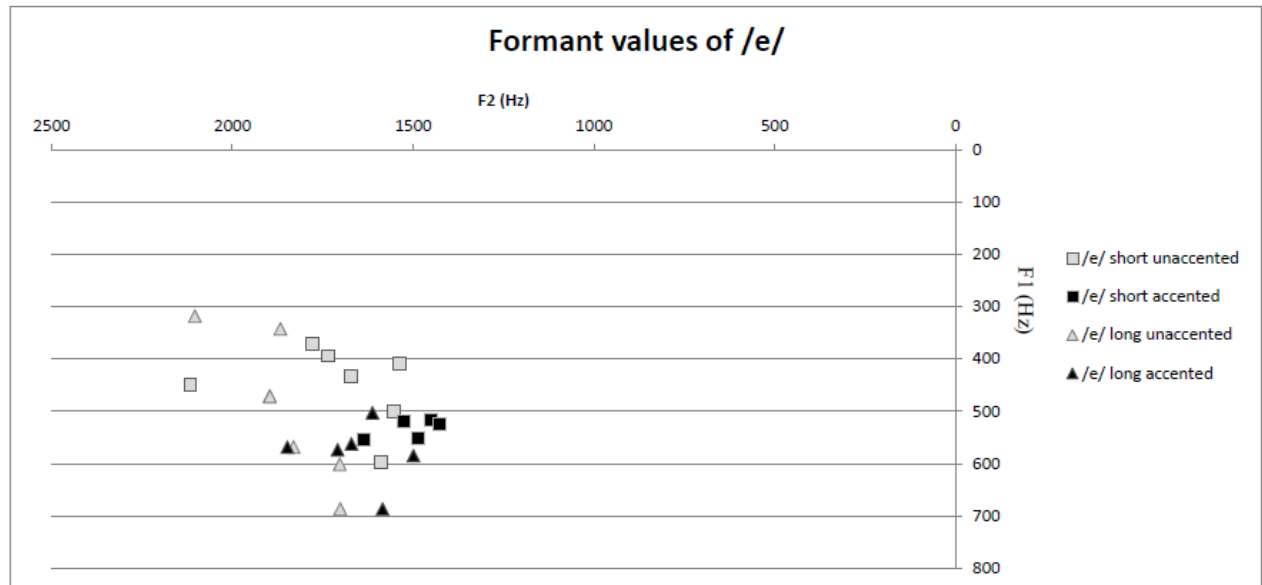


Figure 8. Formant values of accented and unaccented long and short /e/

The plot in Figure 8 illustrates formant values of /e/ in Arapaho. The variants of /e/ are quite widely dispersed depending on the accentuation with short accented variant being the most central one and with long unaccented variants tending to be more peripheral.

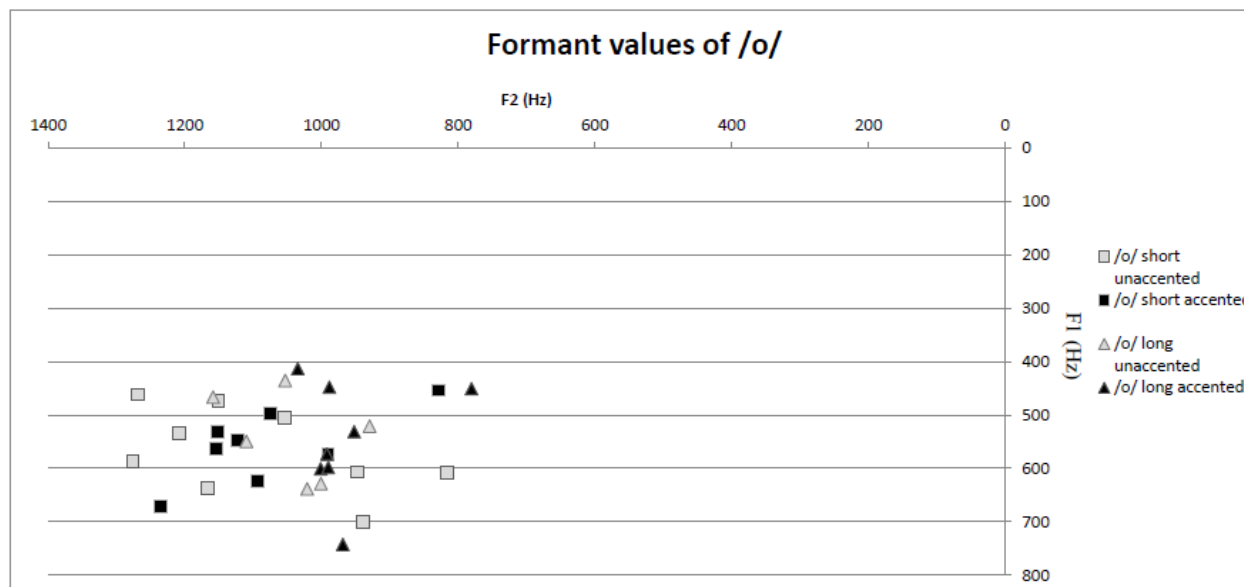


Figure 9. Formant values of accented and unaccented long and short /o/

The patterns of dispersion of the versions of /o/ plotted in Figure 9 are not very clear. However, long accented vowels seem to be the closest to the periphery and short unaccented vowels tend to be situated closer to the central part of the vowel space.

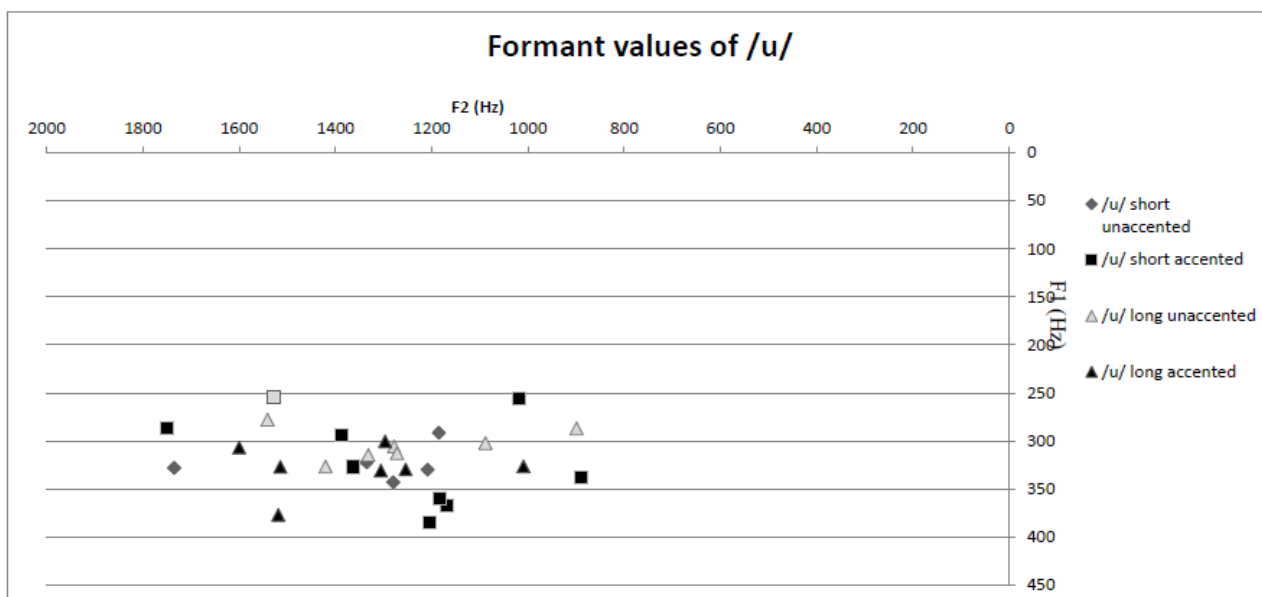


Figure 10. Formant values of accented and unaccented long and short /u/

The allophones of /u/-/i/ do not exhibit specific patterns that would result from the stressed vs. unstressed position.

Several important observations can be made regarding the measurements presented in Tables 8 and 9, and plotted in the Figures 6-10:

- Phonemic inventory of the Arapaho vowels may be more precisely described with the vowels /i/, /i/, /e/, and /ɔ/, rather than /i/, /ʊ/, /ɛ/, /ɔ/ as it was thought before. That is, the vowel represented with orthographic *u* is central close rather than back close, and the vowel represented with orthographic *e* is close-mid rather than open-mid. The choice of /i/ over /ʊ/ seems to be supported not only by phonetic evidence, but also by diachronic origins of the sound. The surface form /i/ (or /u/) is derived from Proto-Algonquian /i/ (Goddard 1974).
- Both long and short variants of the vowels /e/ and /ɔ/ seem to exhibit some changes in quality when accentless; /ɔ/ gets fronted and is shifted toward [ə], /e/ gets fronted and raised, it is shifted toward /i/.
- Unaccented vs. accented allophones of /i/ and /u/ do not show significant changes in quality, which seems to be cross-linguistically common since the peripheral vowels tend to be more stable (see Crosswhite 2001 for a detailed discussion).
- Long vowels, both accented and unaccented, are more peripheral, while short vowels are more central. This is also natural cross-linguistically, because a speaker has more time to produce a more “prototypical” variant of the vowel.

The pattern of quality changes in unaccented vowels of Arapaho is illustrated in Figure 11:

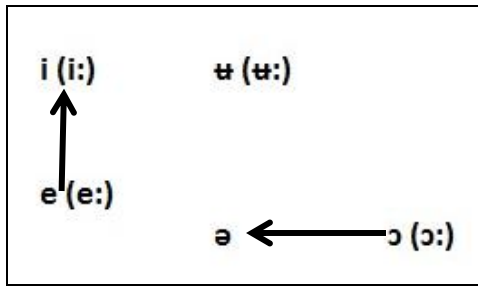


Figure 11. Quality reduction of the Arapaho vowels

Changes in quality in accentless vowels suggest that quality reduction can be an additional cue of accent in the Arapaho language. This observation might mean that prominence in this language functions very much like prominence in stress-accent systems where the primary cue of prominence is usually accompanied by several secondary cues.

4.7 Prominence and amplitude

Amplitude seems to be the most problematic variable in defining cues of accent. It is possible that “intensity variation will never have communicative significance, for the simple reason that intensity is too vulnerable to environmental factors (noise, head movements, objects passing between the speaker’s mouth and the listener, etc.)” (Sluijter 1995, 7). Although previous study of interrelations between amplitude and prominence in stress-accent and pitch-accent languages showed that “intensity [is] a very weak cue” and its significance in cuing accent crosslinguistically is “ranked below duration, which in turn ranked below fundamental frequency inflections” (Beckman 1986, 54), in the current research, an attempt has been made to investigate the relevance of amplitude in the word prosody of Arapaho. It has also been noted that “the term intensity in its acoustic sense should not be used for problems concerning speech-forms without further explanation and especially not without a further justification of the method of measurement” (Mol et al. 1956, 211).

“The acoustic correlate of loudness is intensity or the amount of energy which is present in a sound or sequence of sounds, variations in intensity being produced by variations in the pressure of air coming from the lungs” (Cruttenden 1997, 3). Amplitude (the “height” of a soundwave related to intensity and loudness) is usually difficult to analyze reliably. The different influences on the absolute intensity can be of various characters – conditions and quality of recording, position of a speaker in relation to the microphone, emotional or emphatic changes in loudness. Scholars employ different techniques of measuring amplitude in order to maximize the significance and precision of the measurements. One way to measure amplitude would be to measure amplitude peaks in dB: “If one would persist in speaking of a certain intensity e.g. of a sinusoidal sound curve (in spite of its innate variability), one might correlate the concept of intensity with the peak value of the curve, in consideration of the experimentally proved fact that our auditory organ perceives a pure tone as possessing greater loudness when the peak-value of the corresponding sound curve is increased” (Mol et al. 1956 210). An alternative method of computing amplitude is taking measurements throughout the syllable at 10 ms intervals (Beckman 1986). In the analysis of Blackfoot prominence, S. van der Mark measured amplitude peak; average amplitude - decibel values taken at 20 ms intervals were added and then divided by the number of measurements taken (Van der Mark 2003, 187). Since the absolute measurements of amplitude seem to be rather useless for investigation of its relation to prominence, in the current study I measured amplitude peak of the target accented vowel and the peak of the vowel in the immediately preceding syllable. This way of measuring allows for a comparison in the most “local” context. Table 10 shows mean intensity values of accented long and short vowels and mean intensity values of vowels in the immediately preceding syllable²².

²² It should be noted that the amplitude measurements are the least reliable in this study.

	MeanAmp accented vowel (dB)	MeanAmp previous vowel (dB)
í	79.463	74.404
íí	78.151	73.513
é	77.745	75.341
éé	78.572	74.734
ú	78.178	73.557
úú	77.543	71.299
ó	79.988	74.756
óó	76.944	71.687

Table 10. Mean intensity values of accented vowels and vowels in the preceding syllable

Data in Table 10 seem to suggest that accented vowels usually have higher amplitude than a vowel in the preceding syllable. Interestingly, this holds true for both phonemic long and phonemic short vowels. Table 11 and Figures 8 and 9 illustrate this tendency. Intensity is represented with yellow contour on the spectrogram. Vertical blue lines mark the vowel intervals (accented vowel and vowel in the preceding syllable).

Word	Accented vowel	MaxAmp accented vowel	MaxAmp preceding vowel
Cenéénokú3i' = They are sitting down	ú	78.861	71.884
Neecííninoo = I am wet	íí	80.069	73.458

Table 11. Comparison of intensity of an accented vowel and the vowel in the preceding syllable

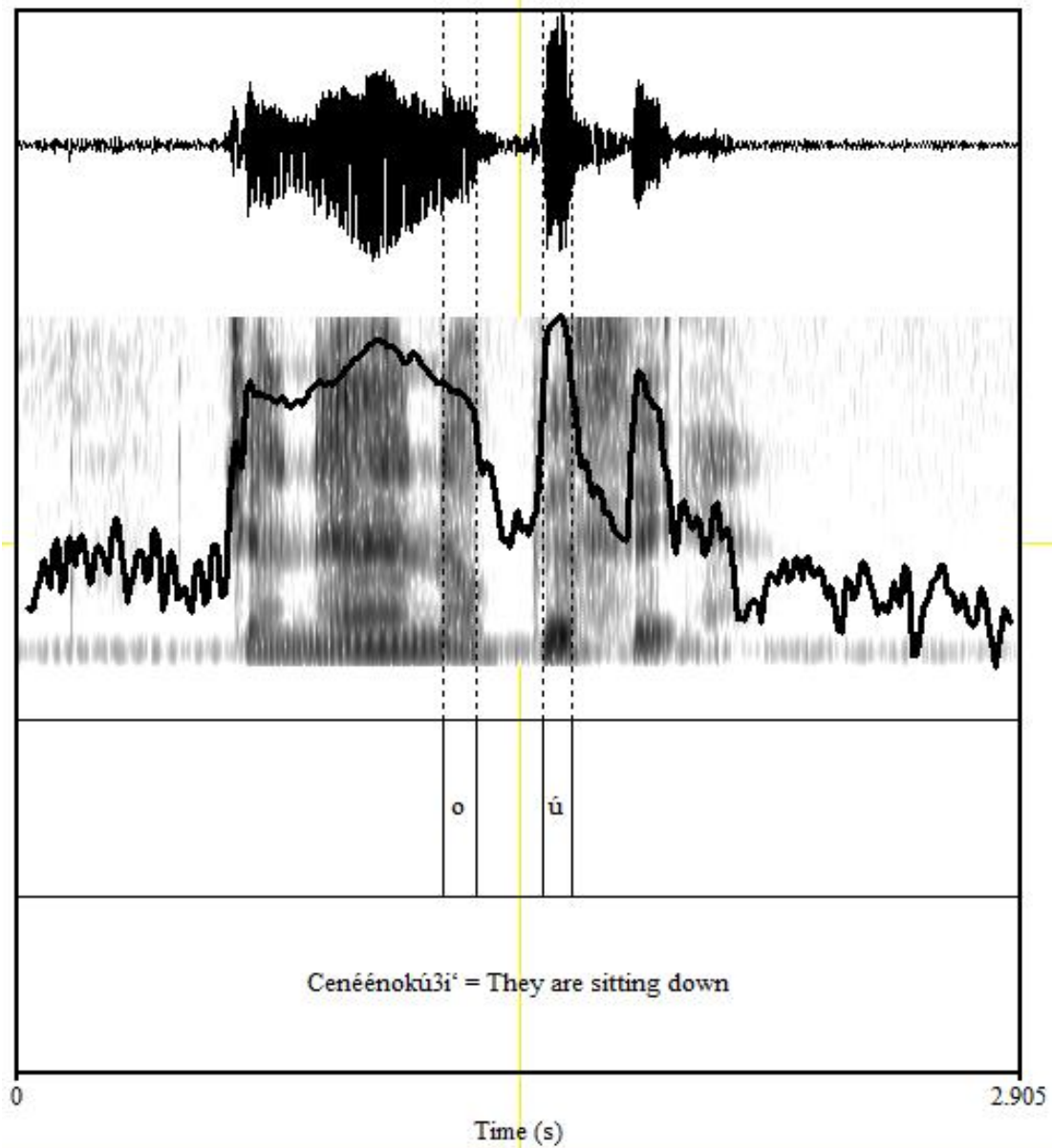


Figure 12. Comparison of intensity of an accented vowel and the vowel in the preceding syllable

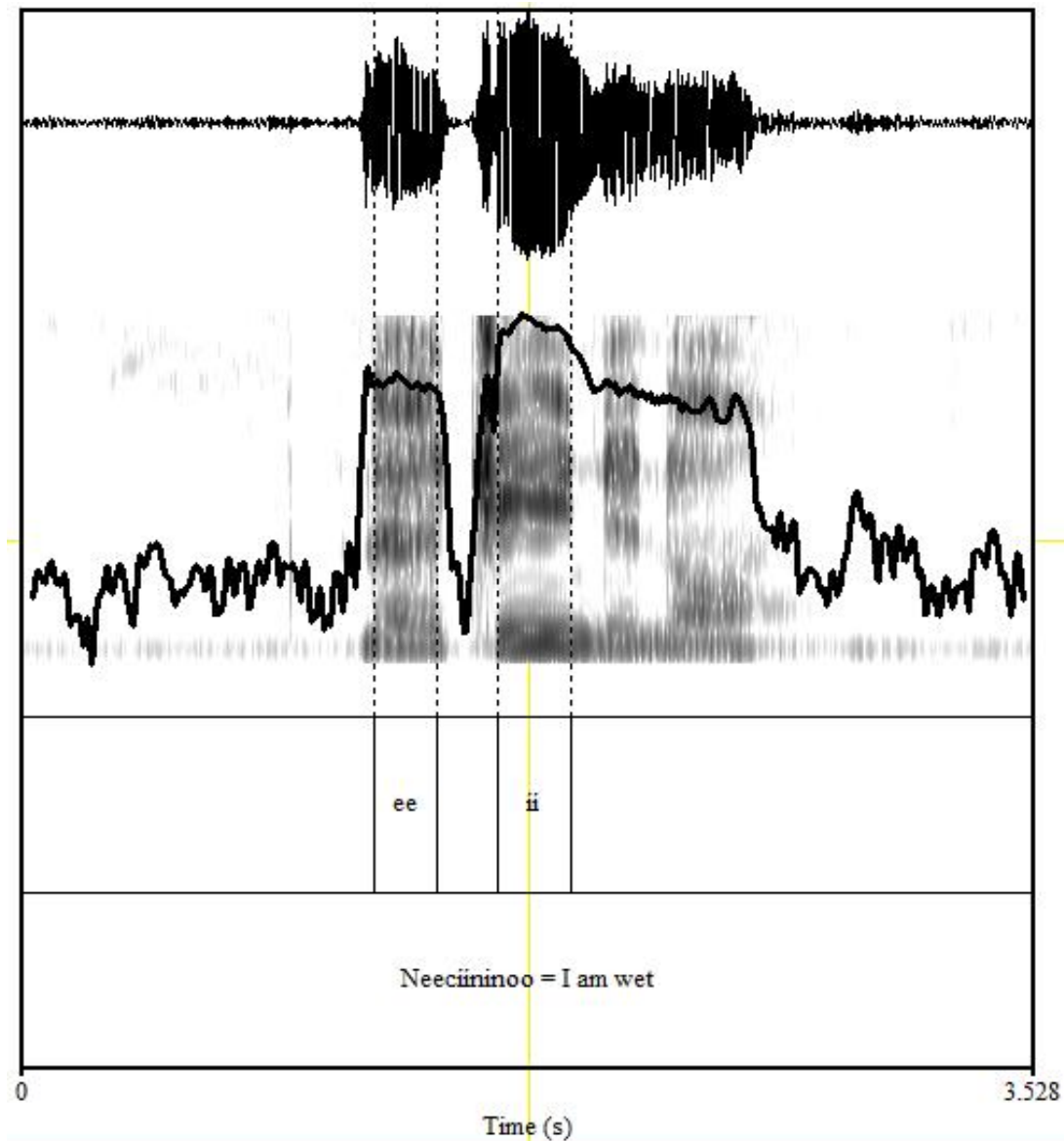


Figure 13. Comparison of intensity of an accented vowel and the vowel in the preceding syllable

The method of measuring amplitude adopted in the current study is of course not ideal. For example, it does not account for the fact that different types of vowels can have inherently higher and lower amplitude. Nor does it account for the influence of the position of a syllable in a word: e.g. the syllable that precedes the accented target vowel might be the initial syllable in a word and might have higher (or lower) intensity due to the markedness of the initial position.

Statistical analysis of the data presented in the next chapter will show how significant and reliable these measurements are.

Chapter 5. Statistical analysis

5.1 Results of statistical tests

Analyses of variance were performed to test the effect of accent on duration, mean F0, the vowel identity (i.e. position of a vowel in the vowel space), and mean amplitude, and to test the correlations between accent and those variables. In this research, an alpha level of .05 was used for all statistical tests.

The results of the ANOVA of Duration, with factors of Accent (accented or unaccented), Vowel Identity (/i/, /u/, /e/ or /o/), and Length (long or short) showed that there is a significant effect of accent on duration ($F_{1,122} = 4.36, p = 0.039$). The interaction between accent and the phonemic length of a vowel was also significant ($F_{1,122} = 5.14, p = 0.0252$). This analysis of variance showed no significant main effect of the position of a vowel in the vowel space on duration of the vowel ($F_{1,122} = 0.19, p = 0.659$). A post hoc test was performed to examine the particular interactions between the variables that were shown to be significant. The plot in Figure 14 illustrates that duration patterns differently for accented and unaccented phonemically short and long vowels:

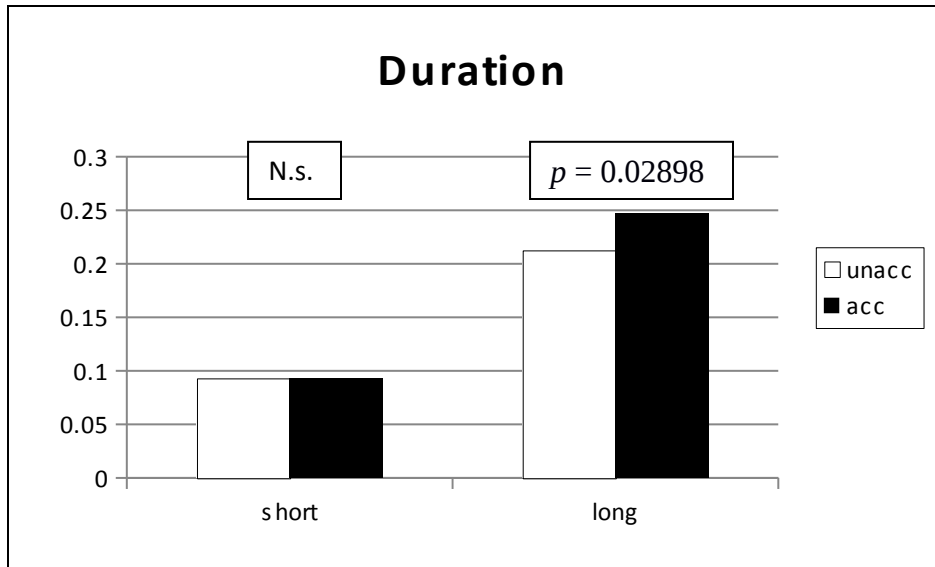


Figure 14. Mean duration in ms for accented and unaccented short and long vowels

A t-Test performed to test the interaction between duration and accent revealed that long accented vowels are significantly longer than long unaccented vowels $t(46.685) = 2.253$, $p = 0.02898$; duration is not a significant cue of accent for short vowels $t(65.986) = 0.0013$, $p = 0.999$.

The analysis of variance of mean F0, with factors of Length (long or short), Accent (accented or unaccented), and Vowel Identity (/i/, /u/, /e/ or /o/) showed significant main effect of length (phonemically long vs. short) on mean F0 ($F_{1,122} = 17.29$, $p < .0001$); and significant effect of accent (accented vs. unaccented) on mean F0 ($F_{1,122} = 3.24$, $p = 0.074$); the interaction between the contrastive length of a vowel (phonemically long vs. short) and the accent was also significant ($F_{1,122} = 7.66$, $p = 0.007$). Vowel identity does not have a significant effect on mean F0 ($F_{1,122} = 2.21$, $p = 0.140$). An ad hoc t-Test performed to test the significance of difference in mean F0 between accented and unaccented vowels showed that short vowels have significantly higher fundamental frequency when accented: $t(65.996) = 2.71$, $p = 0.00857$, while for long vowels there is no significant interaction between accent and mean F0: $t(55.229) = -1.136$, $p =$

0.2608. Interestingly, as was predicted, pitch peak is not a correlate of accent for either short or long vowels. The difference between pitch peak of short accented vs. short unaccented vowels turned out to be insignificant: $t(64.064) = 1.0111$, $p = 0.3158$. The difference between the pitch peak of long accented vs. long unaccented vowels was not significant either: $t(65.077) = 1.023$, $p = 0.4365$.

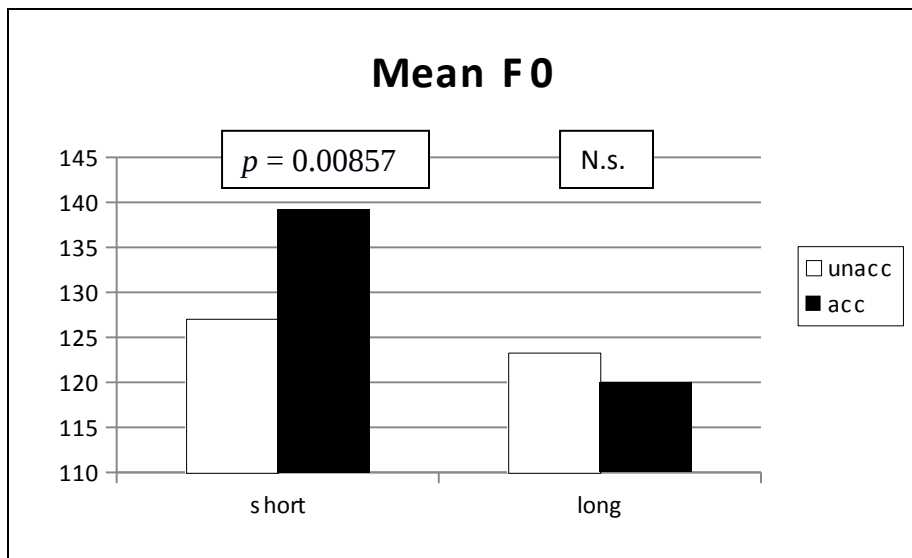


Figure 15. Mean fundamental frequency in Hz for accented and unaccented short and long vowels

The plot in Figure 15 illustrates the significant difference in pitch height between short accented and unaccented vowels.

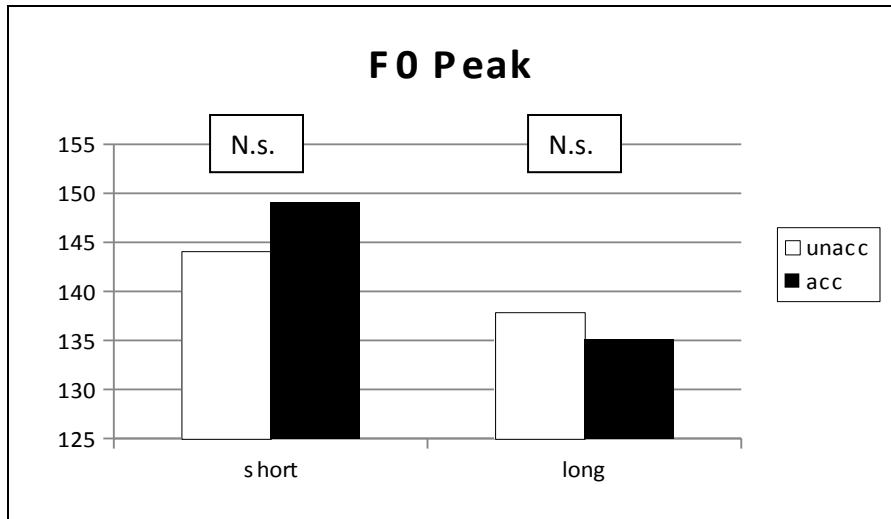


Figure 16. Mean fundamental frequency peak in Hz for accented and unaccented short and long vowels

Analysis of interaction between higher fundamental frequency and accent proved the initial observation: accent, where it is associated with higher fundamental frequency (i.e. *in short vowels*), is cued by *higher mean pitch throughout the vowel* rather than by a pitch peak.

The results of ANOVA of mean amplitude, with factors of phonemic Length and Accent showed significant main effect of Length (phonemically long vs. short) on mean amplitude ($F_{1,122} = 14.91, p = 0.0002$); and a significant effect of Accent (accented vs. unaccented) on mean amplitude ($F_{1,122} = 19.14, p < 0.0001$); the interaction between length and accent was also significant ($F_{1,122} = 10.26, p = 0.002$).

A series of t-Tests was performed to examine interactions between amplitude (mean throughout a vowel and the amplitude peak), length, and the accent.

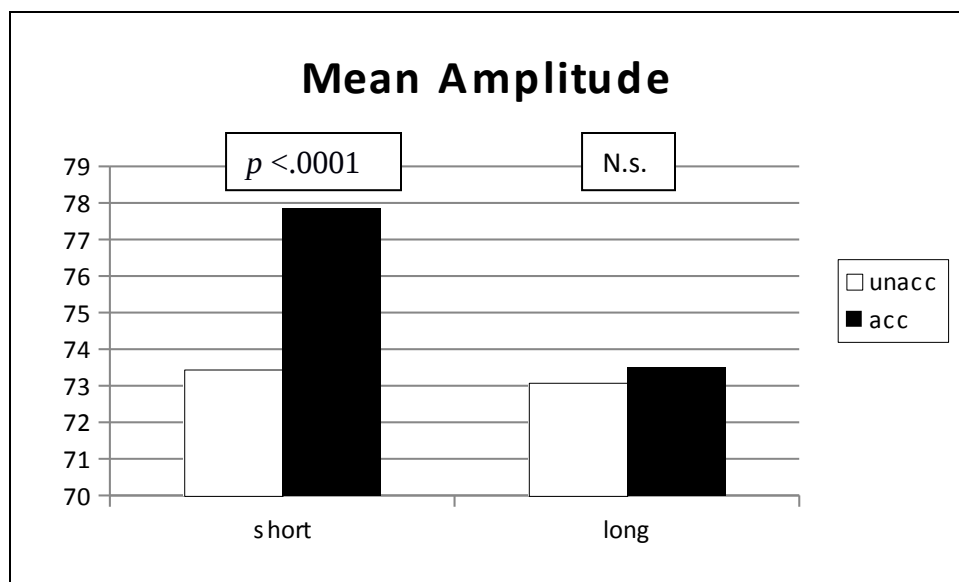


Figure 17. Mean amplitude in dB for accented and unaccented short and long vowels

Short accented vowels have significantly higher mean amplitude than short unaccented vowels $t(58.842) = 5.606$, $p < .0001$. Mean amplitude is not significant for the distinction between long accented and long unaccented vowels $t(52.572) = 0.500$, $p = 0.619$. The same pattern is observed with the maximum amplitude: the mean amplitude peak for short accented vowels is significantly higher than the mean amplitude peak for short unaccented vowels $t(59.845) = 4.972$, $p < .0001$, while this difference is insignificant for differentiating between long accented and unaccented vowels $t(52.885) = 0.097$, $p = 0.9225$.

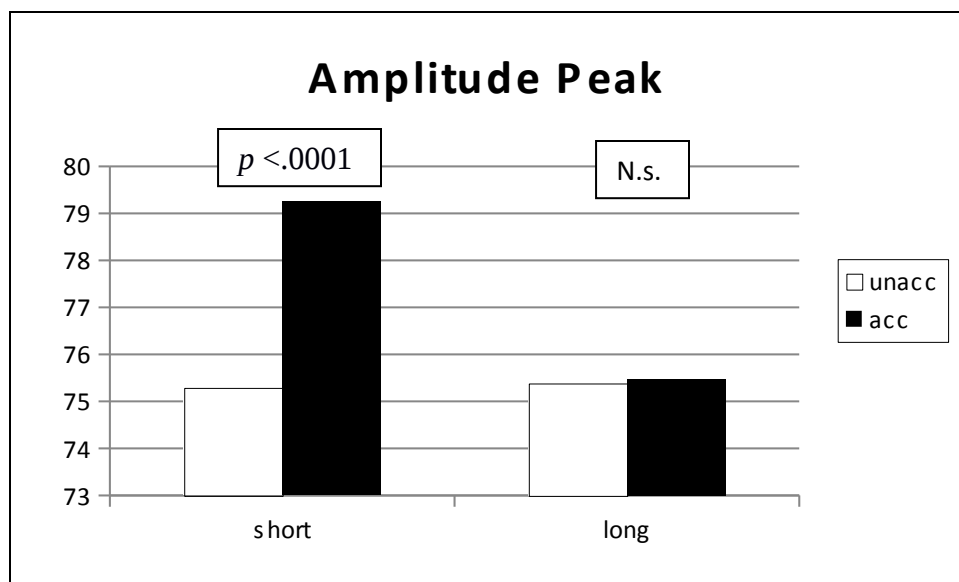


Figure 18. Amplitude peak in dB for accented and unaccented short and long vowels

Results plotted in Figures 14-18 show that *higher mean F0 and higher amplitude are used as the main cues of stress for short vowels in Arapaho*, while *longer duration turns out to be the main cue of accent for long vowels*.

5.2. Discussion

Analysis of variance together with the results of the t-Tests plotted in Figures 14-18 support the observations made in Chapter 3 of the current paper. *The main predictor of accent in the Arapaho language differs depending on whether a vowel is phonemically short or long. Short vowels are characterized with higher fundamental frequency and higher amplitude when accented, while long vowels employ duration as the main cue of accent.* The fact that the system employs several acoustic cues of prominence suggests that the Arapaho language should not be analyzed as a pitch-accent language.

Table 12 summarizes the previously existing ideas about the accentual system of the Arapaho language that were empirically tested in the current research:

Prediction	True or False	Comments
Arapaho is a pitch-accent language	F	Whether we use the term <i>pitch-accent language</i> in its strict phonetic sense, or as a phonological characteristic of a language that follows the principles of obligatoriness and culminativity of accent, Arapaho does not function as a pitch-accent language.
If Arapaho turns out to be a stress-system, it will have no less than and no more than one designated unit per word.	F	The Arapaho language does function like a stress system from the phonetic perspective. However, it shows severe breaches of culminativity of stress allowing for up to 5 prominent syllables per word ²³ .
Modulation of fundamental frequency is the main cue of	F	Modulation of fundamental frequency is <i>one of the cues</i> of

²³ As I have mentioned earlier, although the phonological and phonetic status of multiple accented syllables in an Arapaho word remains unclear, it is important that an Arapaho word can have up to five accents as part of the lexical representation.

accent		accent for only one group of vowels – for the phonemically short vowels.
Arapaho would avoid using duration as a cue of prominence	F	According to the Functional Load Hypothesis, Arapaho should avoid using the phonemic property of length to mark prominence. However, <i>longer duration is used to cue prominence in phonemically long vowels.</i>
Long and short vowels would use the same acoustic cues of prominence	F	This assumption is basic and yet it does not hold true for the Arapaho data in the present analysis. While <i>accent in short vowels is marked with higher fundamental frequency and higher amplitude, accent in long vowels is cued by longer duration.</i>

Table 12. Characteristics of the accentual system of Arapaho

The overview of theoretical scholarship, the data, and the analysis provided suggest that there are at least two possible ways to interpret the status of the Arapaho language in the word-

prosodic typology. The first way is to admit that Arapaho does not fit into any of the three traditional categories. The system does not function as a pitch-accent system since pitch is not the only phonetic cue of accent; it is not a stress system because of the breaches of the principle of culminativity, and, finally, Arapaho cannot be analyzed as a tone language since neither phonetic nor phonological tonal analysis would account for the features of the system. If we choose to accept these conclusions, we have to admit that standard threefold typology fails to account for the existing linguistic data and needs to be revised. The second way of interpreting the Arapaho system would be to call it a stress system. Indeed, as the analysis in Chapter 4 and in the current chapter shows, acoustically, Arapaho marks prominence with a set of features all of which are used by the stress languages. Phonologically, there is only one parameter that stops us from calling it a stress system, namely, allowance for multiple prominent peaks per a lexical unit. If we adopt this second way of interpreting the word-prominence in Arapaho, we inevitably have to revise the notion of stress systems taking into account polysynthetic languages that can have many more syllables in a word than the “prototypical” stress systems such as English or Russian.

Chapter 6. Conclusions

The current research has investigated the acoustic nature of Arapaho prominence. This thesis has pointed out multiple issues in the existing prosodic typology and in the methods of empirical study of cues of prominence. The review of theoretical literature on prominence intends to highlight existing approaches to the variety of word-prosodic systems of the world. The main tendency in the theory of prosodic systems displays a shift from strictly defined and clearly divided types *stress (-accent)* – *pitch-accent* – *tone languages* toward a theory that would be able to account for a much more diverse variety of systems including those that seem to be mixed or ambiguous (Van der Hulst 1988, 2011; Hyman 1977, 2009; Remijsen 2002, 2003 among others). This review shows how difficult it is to assign a system like Arapaho to some specific typological category. Phonologically, prominence in Arapaho does not function like stress in the traditional interpretation of the term – the system exhibits severe breaches of the principle of culminativity. It is important to note once again that an Arapaho word is very different from a word in the languages that are traditionally described as “prototypical stress systems”. A word in Arapaho can oftentimes consist of 8-12 syllables and would be translated into Indo-European languages with a whole phrase. Breaches of the principle of culminativity in this case seem physiologically, rhythmically and perceptually natural. At the same time, I have shown that accent in Arapaho might function very much like accent in stress systems in that it is a morpho-lexical feature; the accent shifts depending on morphemic, morphological, and lexical properties. On the other hand, the syntagmatic rather than paradigmatic nature of prominence in Arapaho contrasts this system to tonal systems. The review of prosodic literature also shows that phonetic difference between pitch-accent and stress-accent languages is commonly claimed to lie in the physical cues of prominence. Pitch-accent languages are said to mark prominence solely

with modulation of fundamental frequency while stress languages employ some combination of cues. In this regard, the current research shows that Arapaho does not fit into the pitch-accent category. Yet another problem with categorization of Arapaho is posed by the ambiguity of opposition word-prosody vs. phrase-prosody, for in this language a phrase can often consist of only one long verb. An overview of methodological literature on experimental procedures for studying cues of prominence was provided in Chapter 4. Discussion of methods of acoustic analysis of such variables as fundamental frequency, duration, spectral quality, and intensity illustrates the challenges of designing a controlled study of correlates of accent. Multiple factors such as position of the word in a phrase, position of the syllable in a word, consonantal and vocalic environment interfere with acoustics of word-prosodic phenomena. In the current research, attempt has been made to reliably account for the differences between accented and unaccented vowels in Arapaho.

This thesis reveals new information about phonetics of Arapaho. To summarize, experimental study of acoustic cues of accent in the Arapaho language allows me to make the following conclusions:

- Contrary to the traditional analysis of this language, Arapaho can hardly be called a pitch-accent language. Prominence in Arapaho is not cued exclusively by higher fundamental frequency. From a phonetic point of view, Arapaho functions more like a stress-accent system that deploys a set of phonetic cues to mark prominence, although it violates the phonological principles of obligatoriness and culminativity. The current study and the analysis of the idea of culminativity of accent raise typologically crucial issue of the role of the notion of *word* that we use to describe units that are often incomparable across languages.

- Phonemically short vowels differ from phonemically long vowels in the correlates of accent.
- Higher pitch and higher amplitude are correlated with accent in short vowels, while longer duration constantly accompanies accent in phonemically long vowels.
- Mid vowels (both short and long variants) exhibit some changes in quality when accentless; /ɔ/ gets fronted and is shifted toward [ə], /e/ gets fronted and raised; it is shifted toward /i/. Vowels /i/ and /u/ do not show significant changes in quality when unaccented.

Throughout this thesis, I have already mentioned multiple issues in the phonetics and phonology of Arapaho that need to be investigated. Studies of the phonetic system of the Arapaho language are in their initial stage; phonetics of this language is practically undescribed. Description of just the vocalic system of this language would include investigation of the following issues:

- perceptual hierarchy of correlates of prominence;
- acoustic properties of triple-vowel sequences;
- hierarchy of accents in a word;
- cues of prominence in their relation to short, long, and triple vowels;
- levels of quality and quantity reduction and their dependence on the position of an accentless syllable in relation to an accented syllable;
- correlation between reduction and contour phenomena;
- accentual influences on consonant production;
- interrelations between word-prominence and phrasal prosodic phenomena.

The list of unstudied issues in the vowel system of Arapaho can be much longer since a thorough investigation of the phonetic system of this language has never been carried out. Eventually, a detailed description of suprasegmentals in understudied languages can reveal strengths and weaknesses of the traditional prosodic typology and can open new paths for cross-linguistic phonetic investigations.

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Appendices

Appendix 1.

List of words read by the Arapaho speaker (accented target vowels)

Read each word of the list twice

héétbobóóteenebé3en	I will respect you
henééneti3é3en	I am speaking to you
nih'e'íno'	He knew it
Héétwonbénenoo	I will go drink
Heetwóteikúútoné3en	I will phone you
Teebkúútiinoo	I have broken it
Nihsé'sinénee	You (pl.) fell down
Héétwoníniibéi'inoo	I will go sing
Nih'onínoo'óót	It fell down/over
Héétnoohówoot	He will see her
Níí'eenówoot	She likes him
Héétwonbenénee	You (pl.) will go drink
Nihtebénowoo	I broke it
Béteenó3ii	Medicine (holy) arrows
Coo3óni'	Prairie dog
Héétnii3óhowoonoo	I will spread it on bread
Nih'iténowoo	I got it
Héétceh'e3íhoot	He will listen to her
Noonsíh'ebínee	You (pl.) are drunk
Nihcebíseenoo	I walked
Nihteesénowoo	I put it on s.t.
Héétwonceenókunoo	I will go sit down
3óó3eenówoot	He remembers her

Héétnoowúseenoo	I will walk downwards
Nonóóhowóó3i'	They see them
Héétwotééseenoo	I will go into town
Nonó'otéése'	It is very windy
Héétnoohowúnee	You (pl.) will see me
Nihcowouwú3i'	They swam (by)
Héétnoouxúseenoo	I will walk across
Héétcinkú3oot	He will release him
Nihtoukú3oot	He tied him up
Híínenííninoo	I am manly
Necííninoo	I am wet
Bíxooxúnee	Love her!
Nihbíi'inóu'u	They found it
Bíxooxú3i'	They love me
Nonookúnóo'oo'	It is turning white
Tenéii'ookú3i'	They are standing still
Níí'eenéétowoo	I like it
Héétwoteeséénee	You (pl.) will go into town
Nihtoyóóhowó'	I waited for him
Nookúwuno	Silver (white) berries
Cenéénokú3i'	They are sitting down
Nih'ésihííhoot	He hurt him
Héétce'iinééseenoo	I will turn back around
Nenii3óónoot	He is accompanying her
Hoohookééninoo	I am crazy
Nonóó'oenokú3i'	They are sitting around s.t.
Héésookú'oonoo	I am watching

Nih'esíniihin	You hurt me
Není'ookú'oonoo	I am looking around
Biixóó3oot	She loves him
Nénii3óóteeni'	It is braided
Heesíiniinoo	I am injured
Nonóóhowó'	I see him
3ebóóxonó'o	Overseas, across the ocean
to'uu3i'eibexóókee	['short faced mountain lion'] bobcat
Nih'i3kúú3oot	He seized him
Hoowúúni	Not
3íi'ookúú3i'	They are standing up
Hoowúúhu'	Downhill

Appendix 2.

List of words read by the Arapaho speaker (unaccented target vowels)

Read each word of the list twice

hee'ín-owoo	I know it
nenii3ín-owoo	I have it
honoosóó'	It is raining
woxeeneet-	Think badly about s.t.
bii3eesnoko'	Scalp (c.f. bei3ees)
tonouku3óó'	Tangled
héé3neebeskóótee	Soft corn
hookecii'óó'oo'	To become little, small
ceceecéisóho-	Done in a sacred way
hineenókoyoo	Main pole at back of tipi
nóooxunéhii	Speaker, person who is speaking
bisecei'óó-	Sweat
ceceecéi	Western water hemlock
hécesbetee3óó	Angel
hééyei nookéih	Harrier hawk
ceceecéihii'ini-	In a blessed way
hii3oowotoo	Womb (sp?)
hiixonéihi-	Useful
touku3eibéi'ci3éi'i	Chain
nonookuce'ée'	Turnip
hecesiitéihii	Dwarf, little person
bee3osóho'o	Sign language
césisih'ohu-	Begin to fly

hiixonih-	Useful to s.o.
nonookucoyóó'	Turnip
hecesiinóhoé	A apint (measure)
hinonó'eisóó	Young Arapaho person
néetinokóóyei-	I am so thirsty!
tóuku3eti-	Tie oneself up
nóonowóón	You're intruding in what I'm doing
yéyeinoxuus	Hairgrass
sei'kuu3óó	Playing card
touku3eino'oowu'	Police station
hii3ohwóót	Any kind of spread
cesisih'ohu-	Fly away
tóuku3etiit	Bra, brassiere
honóuuhuutónoot	To climb s.o. or to s.o.
nisonóxoh'óe	Leavening agent such as baking powder or yeast
béi'ci3e'	Metal, iron, steel
notónihiinén	Male nurse
béi'ci3eiséénok	Cable; chain
béi'ci3eiyeini3ee-	To have iron or metal horns
bei'ci3inooo	Iron pot for cooking
césisihcehi-	Start running, start moving rapidly
cooniitetén-	Unable to reach or get to s.o.
noo'óeeniihi'	Around
niiseekuunó3onohóe	Marriage license
noo'oekuu3-	To make s.o. go around
sei'kuu3éi-	To play cards
3ó'o'wuuci3óo	Plow

nooxunéihii

Master of ceremonies

touku3éihii

Police officer