TOHONO O'ODHAM SYLLABLE WEIGHT:

DESCRIPTIVE, THEORETICAL AND APPLIED ASPECTS

by

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DEDICATION

for Kiyoteru and Reiko Miyashita

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ABSTRACT

This dissertation is a model of a unified study of three linguistic aspects: description, theory and application. Tohono O'odham syllable weight is investigated within these linguistic aspects.

I propose that O'odham diphthongs are categorized into two groups based on their weight: light (monomoraic) diphthongs and heavy (bimoraic) diphthongs. This is opposed to generally understood diphthong classifications (i.e., falling vs. rising). My conclusion is supported by empirical facts, including morpho-phonological and phonetic phenomena. The generalization is theoretically accounted for within the framework of Optimality Theory (McCarthy and Price 1993, Prince and Smolensky 1993).

Moraicity of the light/heavy diphthongs and short/long vowels are analogous, and the larger classification of Tohono O'odham vowels is made: Class L (monomoraic vowels) and Class H (bimoraic vowels). However, the distribution of the vowels depends on syllable type: stressed, unstressed and irregularly stressed. This dependency is accounted for by the following: i) Predictable moraic structure is not specified in input (this is explained with a proposed constraint, MoraIndispensablility or MI); ii) Moraic specification is in the input only where it must be lexically specified (long vowels and irregularly stressed diphthongs); iii) Light diphthongs surface as monomoraic due to the loss of a mora. In order to account for the relationship between the unstressed position and light diphthongs, I propose a constraint, PositionalDiet, a relative of the Stress-to-Weight Principle or SWP (Prince 1990).

Evidence for the diphthong classification comes from an acoustic study of a native speaker and learners of Tohono O'odham. In addition to supporting the classification, the differences between English and Tohono O'odham speakers' treatment of diphthongs is explained with respect to the fact that English diphthongs are always heavy. Finally, implications of this study for Tohono O'odham language teaching are discussed.

CHAPTER 1: INTRODUCTION

1.1 Native American Linguistics - Introduction

Sound is what makes a language alive. Many linguists who work on Native American languages focus on syntax, believing that its study is the primary way to preserve and maintain a language. Some work on systems of syntax (word order) and morphology (word formation). These descriptive studies are important for language maintenance. However, if we work exclusively on syntax and morphology based on the idea of language preservation, it is not language maintenance. A language can be maintained or kept alive only when native speakers exist. Though various linguists may document the grammar of a language, without people who use and speak it, the language is considered dead. Linguists who work with the aim of language maintenance need to consider ways to ensure that languages stay alive. This suggests that a contribution to language education is necessary in research. Also, when a language is spoken, sounds are the direct means of communication. When a word is pronounced incorrectly, the word may not convey the intended meaning. Therefore, the study of the sounds of a language is indeed important for those working towards language maintenance. When a word is pronounced correctly, the word is recognized as a word in a certain language and the hearer can process its meaning, also contributing to language maintenance.

1.2 Focus of Dissertation

In this dissertation, I focus on Tohono O'odham syllable weight, and also provide phonological insights that can help language maintenance efforts for Tohono O'odham. This dissertation is unique because it exemplifies the three different linguistic goals relevant to language maintenance. These are 1) accurate description, 2) useful analysis, and 3) practical application. This dissertation offers each of these regarding Tohono O'odham. In order to successfully contribute to the literature supporting language maintenance in Tohono O'odham, it is written to be accessible to a varied audience. This work can be read not only by linguists, but also by those who are teachers of Native American languages and those who are interested in language maintenance as it relates to the sound structure of the language. For this reason, I provide a brief introduction covering linguistic ideas and theories in this chapter. Readers who are familiar with linguistic theory may chose to skip these introductory sections.

1.3 Overview of Linguistics

This section provides background about linguistics and phonology. In linguistics, three major categories of language structure are often considered: *phonology*, *morphology* and *syntax*. *Phonology* is the study of the sound pattern of language. It explains how the sounds are distributed in a word and how sounds are changed when the word changes its shape. For example, in English, there is a phenomenon called aspiration. Aspiration is extra airflow which comes immediately before a consonant when the sound is pronounced. This aspiration occurs along with voiceless consonants /p/, /t/ and /k/ in English when they are in syllable-initial position. The word *pit* [p^hɪt] has this aspiration but *spit* [spɪt] does not. In phonological research, such sound variation based on the arrangement of sounds is analyzed, and this type of linguistic study is an example of phonology. This dissertation examines phonology in Tohono O'odham.

Morphology is a study of word formation. It explains how words are constructed and examines the function of the smallest meaningful units that make up words, called *morphemes*. For example, within the English word "incomplete", *in* and *complete* are considered morphemes. The morpheme *in* has the effect of negating the meaning of "complete", the morpheme that follows and is attached to it. This type of linguistic study is morphology.

Syntax is the study of sentence structure. In this field, the formation of different types of sentences is analyzed. For instance, English word order is Subject (S), Verb (V) then Object (O), as shown in (1a). The subject begins the sentence, and the verb comes next followed by the object. Some change occurs when we form question sentences. As shown in (1b), a question form of the sentence (1a) has a different word order. The *wh*-word *who* is now placed in the beginning of the sentence, and this results in OSV order.

(1) **English Word Order**

a.	John	kissed	Mary. (S, V, O)	
	Subject	Verb	Object	
b.	Who	did	John	Kiss? (O, S, V)
	Object	Auxiliary verb	Subject	Verb

Tohono O'odham sentences behave differently from English sentences. The background of Tohono O'odham syntax and morphology is given in section 1.5.1. These three fields are the major categories in linguistics. Again, my dissertation focuses only on phonology. The theoretical background in phonology is given in the section 1.3.2 and theoretical framework is in 1.3.2.4.

1.3.1 Linguistic Contribution of the Dissertation: The Three Aspects

The three fields, phonology, morphology and syntax are analyzed in terms of three different linguistic aspects, all of which are explored in this dissertation. They are *descriptive*, *theoretical* and *applied* linguistics. This dissertation is unique because it contributes to these three different areas of linguistics. The following section outlines each linguistic aspects, as well as the contribution that this dissertation makes to each.

1.3.1.1 Descriptive Linguistics

Descriptive linguistics provides the patterns of language structure, describing the grammar or system of the language based on spoken language. Fieldwork (working with native speakers) is necessary for this area in order to obtain precise information about the language. In terms of descriptive linguistics, my dissertation provides new information for Tohono O'odham linguistics. Due to the fact that O'odham possesses a simpler sound inventory than do many other Native American languages (such as the Athabaskan languages[1]), O'odham phonology has had a secondary status in the field of linguistics (Zepeda 1984). However, I claim that this language has a complex sound system worthy of study.

In Chapter 3, a descriptive study of O'odham diphthong patterns is presented. Two new categories in O'odham are revealed and evidence from reduplication is provided. Also, I describe the syllable structure of O'odham words in Chapter 2. Requirements for O'odham syllables are discussed. A single consonant begins a syllable, but more than one consonant can be at the end of a syllable.

1.3.1.2 Theoretical Linguistics

Theoretical linguistics provides data analyses of language structures and patterns, as well as phenomena that may be described by descriptive linguistics. My dissertation also contributes to the area of theoretical phonology. I use Optimality Theory, OT (Prince and Smolensky 1993, McCarthy and Prince 1993), for the theoretical framework. OT is

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[1] Athabaskan languages such as Navajo and Apache are known to have complex consonant inventory. They include ejective stops such as k', t', etc.

explained in section 1.3.2.4. Patterns shown in the section of descriptive study are accounted for in terms of this theory. Syllable formation and requirements are also accounted for in OT. In Chapter 3, the two groups of diphthongs introduced are accounted for. I also analyze the moraic structure of O'odham syllables in Chapter 3. I define the difference between lexical and non-lexical mora in terms of OT.

Second, moraic theory is used in the analysis of the weight of diphthongs and this is also provided in the framework of Optimality Theory (OT). This shows the input-output relationship to be significant in order to account for the weight difference in the optimal candidates.

1.3.1.3 Applied Linguistics

Applied linguistics is the course of study applying descriptive and/or theoretical linguistics to real-world problems, for example, learning (acquiring) and teaching a language. I explore applied linguistics in Chapter 4. I look at an acoustic study of O'odham diphthongs, which are described and analyzed in Chapter 3. I also conducted a simple experiment with Tohono O'odham language learners and compared their pronunciation with that of a Tohono O'odham native speaker. I found that the difference between diphthongs in Tohono O'odham and English result in translation errors by learners. This error suggests that Tohono O'odham language education should target phonological differences between English and O'odham.

The acoustic study given in Chapter 4 provides a connection between phonetics and phonology. The first step of second language acquisition in O'odham is revealed, making this study an initial contribution to language maintenance in terms of language education.

1.3.1.4 A Unique Contribution

As I mentioned above, my dissertation contributes to these three aspects in linguistics. My attempt is to contribute to the study of linguistics as a whole. It is usual for a linguist to select only one aspect and look at one single phenomenon closely. My dissertation, however, is an example of how to understand and approach these three areas as one. I utilize the basic components of these aspects in order to show this uniformity.

Descriptive linguistics provides basic sources for other fields in linguistics: theory and application. Theoretical understanding leads to prediction, explaining predictable phenomena and providing subsequent predications. Such predictions may help language education by creating a basis for appropriate teaching materials or teaching manuals. Chapters 3 and 4 especially demonstrate how I unite these three aspects.

1.3.2 Phonology

In this dissertation, only phonology is treated and no morphological and syntactic analysis is explored. In order to understand the analysis and description, an appropriate phonological background is necessary, as I provide in this section.

1.3.2.1 Phoneme and Sound Inventory

Sounds that exist in a language are called *phonemes*. A phoneme is a single sound recognized by a native speaker of a language that can distinguish meaning in words. For example, [p] and [b] are phonemes in English because the word 'pit' would change its meaning if the initial phoneme [p] is changed to [b]. The meaning of the word 'pit' is no longer the same when the word is pronounced 'bit.'

When we talk about sounds in a language, we usually mean one "segment", which is either a vowel or a consonant. These are actually phonemes. The following table shows English phonemes with their distinctive features. In the leftmost column, the manner of articulation (meaning how the sounds are created) is described. The top row describes place of articulation (meaning where in a mouth a speaker creates narrowing or closure of the vocal tract in order to make a phoneme).

(2) English Consonants

	bilabial		interdental		alveolar		palatal		velar		glottal
	-v	+v	-v	+v	-v	+v	-v	+v	-v	+v	
stop	p	b			t	d			k	g	ʔ
fricative			θ	ð	s	z	š	ž			h
affricate							č	ǰ			
nasal		m				n				ŋ	
liquid						r, l					
glide		w									

When we use these types of distinctive features, it is possible to treat several different sounds as one group a called natural class. A natural class consists of a set of phonological segments that share at least one distinctive feature, allowing us to analyze phonological sound alternation. For example, [p,b,t,d,k,g] can be grouped into one because they are members of the natural class of "stop consonants." In other words, they all share the same manner of articulation "stop", which is the complete closure of airflow at one point in the vocal tract. Furthermore, the sounds [p, t, k] form another natural class. These sounds are "voiceless stop" consonants. Depending on the arrangement of these phonemes, they are pronounced with extra airflow called aspiration when found in a syllable-initial position. The notion of natural class helps explain patterns like aspiration.

The grouping is based on the 'features' that the members of the group share. This contributes to analysis of sound alternations or arrangement patterns. Such featural distinctions are assumed in this research and Tohono O'odham features are shown in Chapter 2. The Tohono O'odham sound inventory is given in a later section.

1.3.2.2 Syllable

The syllable is an important structure in this dissertation. The syllable is an abstract unit in phonology. People can intuitively count syllables in a word or a phrase. In poetry, for example, one can count ten syllables (beats) per line in pentameter. A syllable can be a word as in 'cat' or 'dog.' A word can also have more than one syllable. For example, *tiger* and *salmon* have two syllables, and *kangaroo* has three syllables.

A syllable can be constituted of one or many segments; a sequence of vowels is included as the peak of a syllable. Consonants can be attached in front of and/or behind the vowel. A consonant preceding the vowel is called an *onset*, and one following the vowel is called a *coda*. The example below is typical. In (3), the two consonants [b] and [r] are in the onset position, and only one consonant [k] is in the coda position. The symbol [σ] stands for a syllable.

(3) Consonant Cluster in Onset

```
brick  [brɪk]
         σ
       / |  \
   onset vowel coda
   b r    ɪ    k
   CC     V    C
```

In the example (4) below, only one consonant [d] is in the onset position, but two consonants [s] and [k] are in the coda position. Hence either position can take one or more consonants in English.

(4) Consonant Cluster in Coda

```
desk [dɛsk]
     σ
   / | \
onset vowel coda
  d    ɛ    sk
  C    V    CC
```

The phonological motivation for the existence of the syllable in Tohono O'odham is described in Chapter 2.

1.3.2.3 Mora

The mora, indicated by [μ], is also an abstract phonological unit. It is smaller than a syllable. One syllable will contain one or two moras. A mora is associated with a vowel, and sometimes with coda. Onsets are moraless[2] (c.f. Hayes 1995, Katada 1990).

Moras are used to determine the weight of a syllable; a heavy syllable has two, and a light syllable has one (Hayes 1989). It is assigned to a vowel and a coda consonant when there is a coda. (cf. Weight by Position in Hayes 1989). A long vowel has two moras (bimoraic) and a short vowel has one mora (monomoraic). A bimoraic syllable is heavy, and a monomoraic syllable is light. Hence, a long vowel is heavy and a short vowel is light. Because of this, we can differentiate long from short vowels. In a language which

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[2] Although the common understanding of mora is that onset does not have mora as mentioned above, there are some exceptional analyses in other languages. Japanese (Katada 1990) syllables dominate mora node, and onset and a vowel are associated to mora node.

distinguishes vowel length phonemically (i.e. where vowel length can trigger a change in the meaning of a word), the difference between monomoraic and bimoraic vowels is considered lexical information, just like featural differences.

(5) **Moraicity of Light and Heavy Syllables**

a.	long	V:	$\mu\mu$	V$\mu\mu$	heavy[3]
b.	short	V	μ	Vμ	light

The quantity of moras in a syllable is often referred to as Weight. A monomoraic syllable's weight is light and bimoraic syllable's weight is heavy. This concept is very important in order to understand the analysis given in Chapter 3.

1.3.2.4 Theoretical Framework: Optimality Theory (OT)

I use Optimality Theory (OT), which was introduced by Prince and Smolensky (1993), as well as McCarthy and Prince (1993) for my theoretical framework. This theory was developed in a computational fashion, based on a very different interpretation of phonology from previous generative (pre-OT) theories.

The pre-OT theories were rule-based. They assumed that a sound change occurs due to the application of phonological rules. The "underlying form" served as a base form from which the derivation started. The "surface form" was thought to be the outcome of the word after the underlying form underwent the phonological rules of the language. This results in the form of the word pronounced. Take Polish for instance. The underlying form of the word *vus* 'cart' is /voz/. Pre-OT theories consider two rules for this word. One is vowel raising. This rule changes the quality of a vowel from a non-high vowel to a high

[3] Sometimes, a superheavy syllable is seen when the syllable has more than two moras. superheavy syllables are not discussed in this dissertation.

vowel when the vowel occurs before a voiced consonant. As shown in (6a), the underlying form /voz/ is changed to "vuz" because of this rule. Then there is another rule: final devoicing. This devoiceing rule forces the final voiced consonant to become voiceless. In (6a), the "vuz" that underwent the raising rule is now changed to [vus] due to this second rule. Hence the correct surface form is derived. However, one weakness of this theory is that if the order of the rules is changed, then the raising rule does not apply anymore because there is no voiced consonant that is the key for the vowel to change the quality. Thus, the incorrect surface form *[vos] is derived.

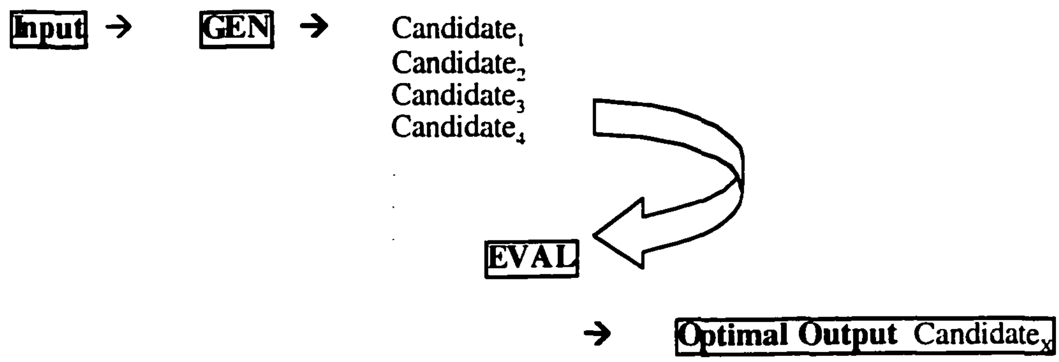
(6) Rule Based Analysis: Pre-OT theory

a.	Underlying form:	/voz /
	raising:	vuz
	devoicing:	vus
	Surface form	[vuz]
b.	Underlying form:	/voz/
	devoicing	vos
	raising	inapplicable
	surface form:	*[vos]

As shown above, the rule-based analysis gives us a step by step analysis of sound alternation. However, it does not always result in correct surface forms.

On the other hand, Optimality Theory does not posit any rule application. Its mechanism is described by three major components: Input, GEN and EVAL. This system is illustrated in (7) below. From the given lexical input, the function GENerator creates an infinite number of possible output candidates. These candidates undergo a process called EVALuation in which they are evaluated by a constraint set. Within the set, constraints are ranked language-specifically. The constraints themselves are both universal and violable. The evaluation of the candidates by the constraints is simultaneously processed, presenting a major difference between OT and rule-based theories. Through EVAL, a correct output form is selected, as illustrated below.

(7) System of Optimality Theory



An evaluation is manifested in the form of a table, or *tableau* as shown below.

(8) OT Tableau

	/input/	constraint α	constraint β
☞ a	candidate A		*
b	candidate B	*!	

As shown in (8) above, there are two candidates: A and B, and two constraints: α and β ranked with respect to each other. Constraint α is ranked above the other constraint β. The asterisk '*' is utilized to indicate that a candidate violates the constraint represented in that column. Note that candidate A violates constraint β, and that candidate B violates constraint α. Although candidate A violates the lower-ranked constraint β, it is selected as optimal. This is because candidate B violates the higher-ranked constraint α, so the evaluation ends at that point with the exclamation mark on the crucial violation of constraint α. As a result, the violation of constraint β for any remaining candidates no longer matters. The evaluation of the lower ranked constraint proceeds only when there is equal evaluation in the higher ranked constraints. Therefore, in the case of this tableau (8), candidate A wins over candidate B, this is indicated by the symbol (☞) beside the correct candidate. Optimality Theory is assumed in the theoretical analysis of this dissertation, with no rule-based analysis given.

1.3.2.5 Language Acquisition and Learning

Many tribal members refer to Tohono O'odham as their native language even though they do not speak it as their first language. In this case, they mean traditional language. For this reason, I use the terms, *first language* and *second language* instead of *native language* in this dissertation. Human beings *acquire* language naturally without instruction, and it happens when they are young. The process is called *first language acquisition*. People are also able to *learn* language by being taught. If a person acquired two languages naturally or without being taught, he/she can have two first languages (Ellis 1994). Learning a language through formal instruction later in life is commonly known as *second language acquisition* or SLA.[4]

When learners produce their second language, they often make errors. Their errors occur because of the linguistic difference between their first language and second language. Since the errors are caused by the use of their first language grammar in their second language production, the process is called *transfer*. I assume this process in Chapter 4, in which an experimental study with both first and second language speakers of Tohono O'odham is provided.

1.4 Tohono O'odham Overview

The language of Tohono O'odham is analyzed in this dissertation. It is spoken mainly by members of the Tohono O'odham nation. Tohono O'odham is an American Indian tribal group formerly known as Papago. Tohono O'odham is the official name of the tribal community, and the name means the "desert people" in the language.[5]

The majority of Tohono O'odham people live within the Tohono O'odham reservation (Figure 1), which is located in southwestern part of Arizona. There are three different reservations for Tohono O'odham in Arizona. The Tohono O'odham reservation is the largest among the three. It is located in the southwest corner of Arizona. The San Xavier reservation, in which the mission San Xavier del Bac can be found, is located just southwest of Tucson. The third reservation is the Ak Cin reservation. This reservation is located near Phoenix, the capital of Arizona. Most O'odham villages are located within the reservation, and several villages are in Sonora Mexico, such as Ṣon Oiḍag, Gi'ito Wak, etc.

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[4] There is a distinction between acquiring a second language as an adult in a natural setting vs. learning it via formal instruction although such the distinction is not treated in this dissertation.
[5] *tohono* means 'desert' and *o'odham* means 'people.'

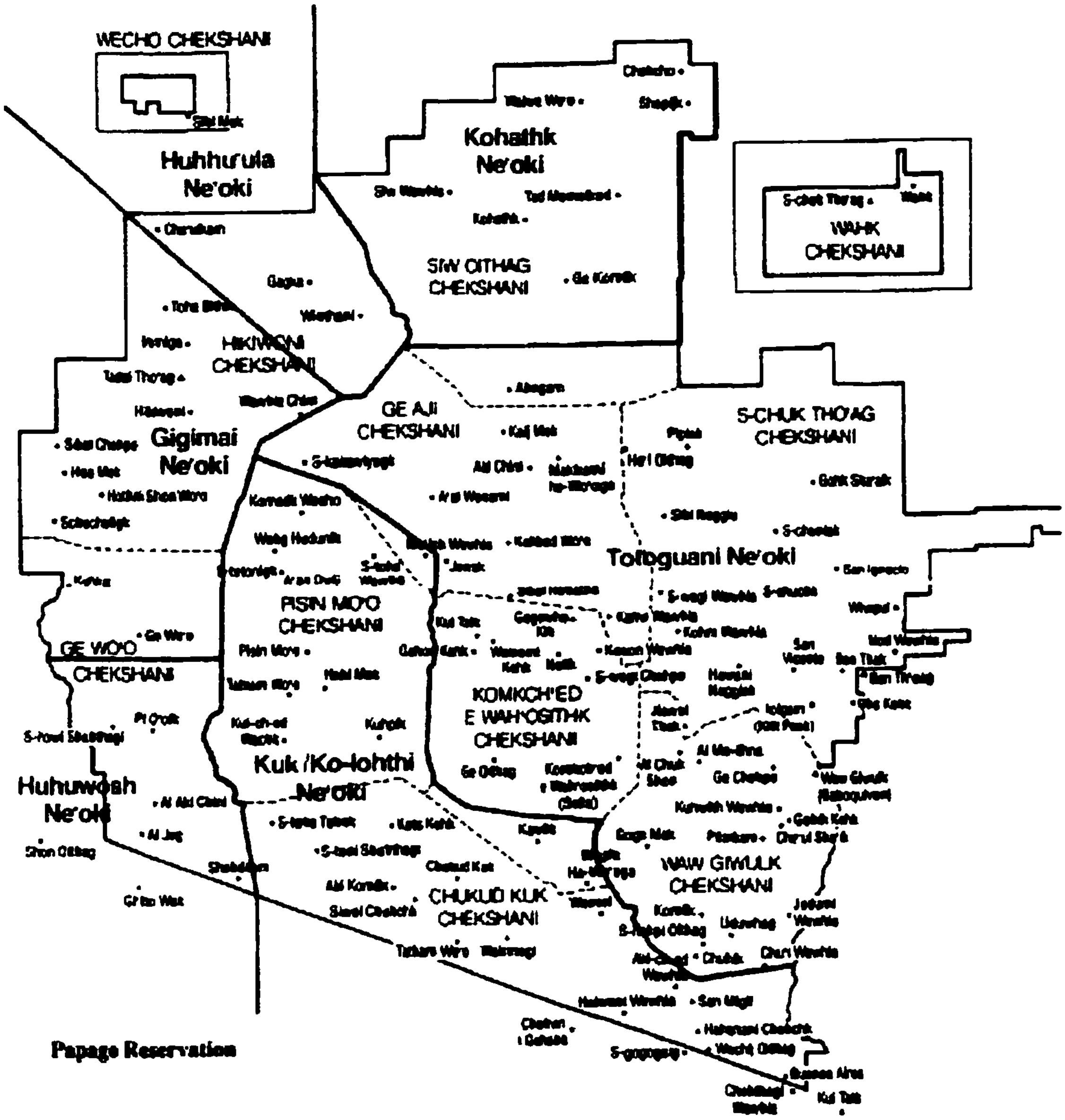

Figure 1, Map of Tohono O'odham Reservation (Saxton, et. al. 1983)

1.4.1 Language Family

The Tohono O'odham language belongs to the Tepiman branch of the Uto-Aztecan language. Tepiman includes Tepehuan (Mexico), *Akĭmel* O'odham, etc. The Pima (Akĭmel O'odham) language spoken around Salt River and Tohono O'odham are two major dialects of the O'odham (or Upper Piman) language. There is *mutually intelligibility* between the two languages. That is, speakers of Pima and Tohono O'odham can understand each other.

1.4.2 Language Status

Krauss (1998) proposed the following classification of language status: Class A, B, C and D. In the four classes, Class A includes most healthy language communities in which the language is spoken by all generations. An example of this group is *Navajo*, spoken in northeastern Arizona and northwesern New Mexico. Class B contains languages spoken by the parental group and older generations only. Class C contains languages spoken only by the grandparental and older generations. Some regions of Tohono O'odham and Navajo fall into this category. The last category, Class D, contains languages spoken only by the very elderly. *Mohave* or *Chemehueve* are example language communities for this class. Languages in Classes B though D are considered *moribund languages* because there are no children speaking the language. This will lead a language to become extinct unless children begin to acquire the language as a first language again (c.f. Crystal 2000, Hill 1983).

Tohono O'odham is often categorized as falling into Class B of Krauss' (1998) classification because the parental generation and older are the speakers of Tohono O'odham. Few, if any children are currently acquiring it as their first language. However, it is difficult to determine the status by rigid classification because the truth varies depending on the area. In the east of the Tohono O'odham reservation, most children's first language is English. This may be caused by the urbanization of the Capital of the Reservation, Sells. In the west, on the other hand, many children's first language is Tohono O'odham. Traditional culture and language are kept in these areas and those who live here seldom encounter the urban culture and language.

1.4.3 Language Education

Children on the reservation are educated in the schools where they are taught in English. Although the O'odham language is taught as a school subject, these language classes may not be effective enough to bring non-O'odham speaking children to bilingual fluency in O'odham and English because the curriculum is only one hour per day. This is a fine program for children who already speak O'odham as their first language to become fluent in both English and O'odham. However, for those children whose families are not speaking the language at home anymore, O'odham language classes are not likely to help them become fluent O'odham speakers.

The ideal situation would be to have more O'odham speaking teachers in schools, and incorporate courses that are taught in O'odham. However, it is difficult to change the program when schooling is provided under the direction of The Bureau of Indian Affairs. In order to improve the situation of the language status, effective teaching methods should be introduced. Generally when a language is taught, pedagogical methods are developed specific to the target language. Thus, it is important to develop teaching materials specific to the O'odham language. Unfortunately, no fully established O'odham teaching methods currently exist. More research on and design of teaching methods for O'odham will need to be considered.[6] This dissertation provides some suggestions for teaching methods that O'odham language teachers may make use of (see Chapter 4).

1.5 O'odham Language Properties

In this section, I outline major language properties in Tohono O'odham. They are divided into the linguistic fields of syntax, morphology and phonology.

1.5.1 Syntactic and Morphological Properties

In this section, I introduce main properties in the syntax and morphology of Tohono O'odham. The following sections provide information on *word order, person number marking, reduplication* and *truncation.*

1.5.1.1 Word Order

Tohono O'odham is known as a language that has *free word order.* Word order refers to the arrangement of linguistic elements in a sentence. English has rigid word order of subject, verb and object, and the interpretation of grammatical relations relies on the word order. For example, when the order of the subject and object is switched, the meaning of the whole sentence changes. In (9a), Mary is the actor and Joe is the receiver of the action kissing. In (9b), on the other hand, Joe is the actor and the Mary is the receiver of the action.

(9) English Word Order

a. Mary kisses Joe.

b. Joe kisses Mary.

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[6] There is an attempt to apply ESL (English as Second Language) methods to Tohono O'odham language education. (Zepeda, p.c.)

In many languages, there is a basic word order even though the order is not as strict as in English. O'odham word order, however, is relatively free. Subject, object and verb can be placed in any order in a sentence. The only restriction is that the sentence must have the auxiliary in second position (Zepeda 1983, Jelinek 1984). In the examples shown in (10) below, there are four rows for each sentence. The first row is the sentence written in the Tohono O'odham orthography, the second row is written in the phonetic alphabet, the third row is the morphological gloss, and the last row is the English translation of the sentence. In the third row, AUX indicates *auxiliary* and DET indicates *determiner*. In the orthography, a long vowel is indicated with a colon, and glottal stop consonant with an apostrophe.

(10) Tohono O'odham Word Order

a. Ban 'o huhu'id g mi:stol.

ban	ʔo	huhuʔid	g	miistol
coyote	AUX	chasing	DET	dog

(The coyote is chasing the cat.)

b. Ban 'o g mi:stol huhu'id.

ban	ʔo	g	miistol	huhuʔid
coyote	AUX	DET	cat	chasing

(The coyote is chasing the cat.)

c. Mi:stol 'o huhu'id g ban.

miistol	ʔo	huhuʔid	g	ban
cat	AUX	chasing	DET	coyote

(The coyote is chasing the cat.)

d. Mi:stol 'o g ban huhu'id.
miistol ʔo g ban huhuʔid
cat AUX DET coyote chasing
(The coyote is chasing the cat.)

e. Huhu'id 'o g mi:stol g ban.
huhuʔid ʔo g miistol g ban
chasing AUX DET cat DET coyote
(The coyote is chasing the cat.)

f. Huhu'id 'o g ban g mi:stol.
huhuʔid ʔo g ban g miistol
chasing AUX DET coyote DET cat
(The coyote is chasing the cat.)

The example sentences above each have exactly the same syntactic elements (words), but each sentence has a different word order from the others. However, they all mean the same thing: *the coyote is chasing the cat*. A language that has the kind of free word order demonstrated above is called a *non-configurational language* (Hale 1983, Jellinek 1984). In line with the only O'odham word order restriction, note that the auxiliary *ʔo* always takes second position in the examples listed. A sentence would be ungrammatical in O'odham if this auxiliary were placed in a different position, as shown in (11) below.

(11) Tohono O'odham Incorrect Word Order

a. *Mi:stol g ban huhuid 'o.
miistol g ban huhuʔid ʔo
cat det coyote chasing AUX
(The coyote is chasing the cat.)

b. *Mi:stol g ban 'o huhu'id.

mi:stol	g	ban	ʔo	huhuʔid
cat	det	coyote	AUX	chasing

(The coyote is chasing the cat.)

The interpretation of a sentence with two third person singular nouns can be ambiguous. In the example sentences in (11) above, the meaning is easily figured out by the relationship between a *coyote* and a *cat*. A coyote is more likely to chase a cat rather than vise versa. When the two arguments (nouns) have the same qualification such as both third person singular, such as John and Joe, then the grammatical relationship is ambiguous. The ambiguity is solved by context (cf. Miyashita et al. 2000).

1.5.1.2 Person and Number Marking

Typologically, O'odham shows similar characteristics to a *pronominal language*. A pronominal language has the characteristic that a sentence can drop arguments (nouns). Having no argument in a sentence is usually possible when the arguments' grammatical relations are indicated via other elements in the rest of the sentence. For example, Spanish can drop a noun because its verb carries information about the person and number of the subject.

In O'odham, a minimal requirement in a sentence is the presence of a verb and an auxiliary. The auxiliary indicates the person-number of the subject, and the characteristics of the object are indicated by the prefix on the verb. In the table (12) below, the six auxiliaries of O'odham are shown. These AUX indicate the number and person of a subject in an imperfective sentence.

(12) AUX (subject, imperfective)

	singular	plural
1st	ʔañ	ʔač
2nd	ʔap	ʔam
3rd	ʔo	ʔo

For example, as shown in (13a), the English translation tells us that the subject of the sentence is *you* (second person singular) and not *Huan*. This interpretation is derived because the AUX *ʔap* indicates the subject of the sentence, who is second person singular. The second person singular pronoun *ʔa:pi* does not need to be in the sentence. A sentence can also occur with a full pronoun as shown in (13b). In addition, the sentence can occur without the proper noun *Huan*. In this case, the object is some person whose person and number is second person singular. The person and number marking of the object is shown in (14).

(13) Example with AUX

a. Huan 'ap ñeid.
Huan ʔap ñɨid
John AUX 2nd sing. subj seeing
(You are seeing John.)

b. Huan 'ap ñeid 'a:pi.
Huan ʔap ñɨid ʔaapi
John AUX 2nd sing. subj seeing you
(You are seeing John.)

c. Ñeid 'ap.
ñɨid ʔap
seeing AUX 2nd sing. subj.
(You are seeing someone.)

The table (14) below shows the verbal prefixes of O'odham. These prefixes indicate the person and number of the object of the sentence. For example, the sentence in (15) has the prefix *m-*, which indicates the object is second person singular. Since this prefix carries the information of the object in the sentence, the pronoun for the second person singular *ʔa:pi* does not have to be in the sentence.

(14) Prefix (Object)

	singular	plural
1st	ñ-	t-
2nd	m-	ʔem-
3rd	ø	ha-

(15) Example with Prefix

Huan 'o m-ñeid.
Huan ʔo m- ñɨid
John AUX 3rd subj. 2nd sing. obj.- seeing
(John is seeing you.)

As shown above, an AUX and clitic element mark all verbal arguments, and full arguments can appear optionally. Jelinek (1984) calls this type of language a *W-type Non-configurational language*.

Another salient morphological property of O'odham is *reduplication*. Reduplication is a morphological phenomenon in which a part of (or a whole) word is repeated in order to indicate grammatical information. In O'odham, reduplication indicates either plurality of a noun (or grammatical argument).

1.5.1.3 Reduplication

O'odham *reduplication* occurs for both nouns and verbs. There are two kinds of reduplication in terms of grammatical function. In the noun plural formation, a singular noun becomes plural.[7]

(16) Noun Plural Formation:

	base	gloss	reduplicated	gloss
a.	gogs	'dog'	**go**gogs	'dogs'
b.	miisa	'table'	**mi**msa	'tables'
c.	makai	'doctor'	**ma**makai	'doctors'

In the noun distributive formation, a noun indicates that the argument is located in several locations. The template for the reduplicant is CVC.

(17) Noun Distributive Formation:

	base	*gloss*	reduplicated	gloss
a.	gogs	'dog'	**gog**gogs	'to be full of dogs'
b.	ciadagi	'gilamonster'	**cic**ciadagi	'to be full of gilamonster'

On the other hand, when a verb is reduplicated, it indicates that the verb's argument is plural. The indication of an argument's plurality differs between intransitive and transitive verbs. When an intransitive verb is reduplicated, the verb indicates that its subject is plural as

[7] The reduplicant's syllable structure is CV. Sometimes the base of the reduplicated form deletes the vowel: *miisa* becomes ***mimsa***, and not ***mimisa***. (cf. Fitzgerald 1999)

seen in (18). However, when a transitive verb is reduplicated, the indication of plurality switched onto the verb's object.[8] as illustrated in (19).

(18) Intransitive Verb Plural Formation:

	base	reduplicated	gloss
a.	cipkan	**ci**cpkan	'working' (subject is plural)'
b.	him	**hi**him	'walking'
c.	kooṣ	**kook**ṣ	'sleeping'

(19) Transitive Verb Plural Formation:

	base	reduplicated	gloss
a.	wakon	**wap**kon[9]	'washing (object is plural)'
b.	ciposid	**ci**cposid	'branding (object is plural)'

In a distributive formation, a verb indicates that the action is occurring in several locations when reduplicated. The examples are shown below:

(20) Verb Distributive Formation:

	base	reduplicated	gloss
a.	ñiʔi	**ñi**ñiʔi	'singing (distributive action)'

[8] Since the plural formation of reduplication occurs for the subject of intransitive sentences and the object of transitive sentences, this property is anologous to ergative/absolutive language. However, since Tohono O'odham does not have morphological case marking, it is hard to determine that this language belongs to the group of ergative/absolutive language. (cf. Dixon 1994)

1.5.1.4 Truncation

Truncation is also an important morphological phenomenon seen in O'odham (Fitzgerald and Fountain 1997, Saxton et. al. 1984, Zepeda 1983). Truncation marks a type of grammatical information by clipping off part of a word. In O'odham, the ending portion of a verb is truncated to indicate that the action (or verb) is in the perfective, which indicates a completed action. (Chapter 2)

(21) **Truncation**

	Imperfective	Perfective (truncated)	Gloss
a.	ñɨok	ñɨo	'talking'
b.	maak	maa	'giving'

1.5.2 Phonetic and Phonological Properties

The phoneme inventory is relatively simple in O'odham. Sounds that are different from English are the high central vowel [ɨ], and retroflex consonants [ṣ, ḍ, and ḷ]. The charts below show the O'odham phonemes.

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[9] Historically, [w] was [p] in Tohono O'odham. The word *wakon* was *pakon*, and its reduplicated form was *papkon*. The pronunciation of initial [p] came to be pronounced as [w] over time. The [p] in *wapkon* is now a remnant.

(22) O'odham Consonants

	bilabial		dental		alveolar		palatal		retroflex	velar		glottal
	-v	+v	-v	+v	-v	+v	+v	-v		-v	+v	-v
stop	p	b	t	d					ḍ	k	g	ʔ
fricative					s				ṣ			h
affricate							č	ǰ				
nasal		m				n					ŋ	
liquid									ḷ			
glide		w										y

(23) O'odham Vowels

	Front	Central	Back
High	i	ɨ	u
Mid			o
Low		a	

1.5.2.1 Orthography

There are three different orthographies used by linguists: Saxon/Saxton/Enos, Mathiot and Alvarez/Hale. The Tohono O'odham tribal council accepted the Alvarez-Hale writing system as an official Tohono O'odham orthography. The above phonemes are described with a phonetic alphabet. The O'odham writing system uses a similar representation to that shown above with minor differences. In the Alvarez-Hale writing system, the retroflex [ḷ] is represented with no dot [l], the palatals [ǰ] and [č] are written without [ˇ], the hi central vowel [ɨ] is represented by [e], and the glottal stop [ʔ] is represented with a single quotation mark [']. In addition, O'odham has diacritics to indicate that a vowel is voiceless.[10] In Tohono O'odham orthography, the voiceless vowel is indicated by the diacritic [˘] over a vowel, while the phonetic alphabet uses [̥] under the vowel.

(24) Corresponding Sound Representation

	Phonetic Alphabet	Alvarez-Hale System
a.	ḷ	l
b.	ǰ	j
c.	č	c
d.	ɨ	e
e.	ʔ	'
f.	v̥	v̆

In addition, a long vowel is represented with a colon [:] after the vowel that is lengthened in the Alvarez-Hale orthography. In my dissertation, all data in Tohono O'odham are represented in a phonetic alphabet, and I use two identical vowel symbols to indicate a long vowel, such as [aa] instead of [a:].

[10] The notion of voiceless vowels varies depending on the literature of Tohono O'odham phonology. Hale (1959) recognizes these vowels as extra short vowels. Zepeda (1983) introduces them as either extra short vowels or aspirated vowels. Miyashita (2000) treats them as voiceless vowels. I use voiceless vowels in this dissertation.

1.5.2.2 Basic Stress Pattern

The concept of stress is important background for this dissertation. In this section, the basic stress pattern of O'odham is briefly described. An understanding of O'odham basic stress assignment is necessary as well. An O'odham word has at least one stress. The stress is always assigned to the first syllable[11] except for a group of borrowed words from Spanish[12] (Saxton et. al. 1983, Moll 1997, Fitzgerald 1999). The examples of initial stress are shown in (25) below.

(25) O'odham Words with Stress

a. ʔáli 'child'

b. báaban 'coyotes'

c. cíndad 'kissing'

d. dáikuḍ 'chair'

e. háaṣañ 'saguaro cactus'

The location of stress can be functional in some languages. For example, a group of English words distinguishes the grammatical categories by the location of stress on words. As shown in (26) below, the location of stress determines whether the word is a noun (N) or a verb (V). (Kiparsky1982, cf. Halle and Keyser 1971).

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[11] In Mathiot's dictionary, non-initially stressed words are found. This represents a very small number in the lexicon, and as such, the data corpus is not big enough to be treated in the analysis appearing in later chapters.

[12] Some loan words in O'odham are borrowed from English. Today, more English words are being borrowed on the US side of the reservation, but the borrowed words from English that are in dictionaries tend to be Pima words.

(26) English Functional Stress

a. cóntest (N) vs. contést (V)

b. cónvert (N) vs. convért (V)

Such a grammatical distinction is never used in O'odham. Shift of stress location will only create ungrammatical words as shown below:

(27) O'odham Words with Wrong Stress

a. *ʔalí

b. *baabán

c. *cɨndád

d. *daikúḍ

e. *haaṣáñ

There is however, a group of O'odham words that receive stress in non-initial position.

(28) Exceptionally Stressed Words

a. pastíil 'a pie'

b. alhúandi 'elephant'

c. gasolíin 'gasoline'

Such non-initial stress, however, appears only in borrowed words (Moll 1997). In these words, stressed syllables are always heavy. The specifics of this pattern are described later (See Chapter 3).

In sum, O'odham stress falls onto the initial syllable with the exception of a group of borrowed words from Spanish (or English). A trisyllabic word receives stress only on the initial syllable if it is monomorphemic, and the other two syllables remain unstressed. In polymorphemic trisyllabic words, the first syllable receives primary stress and the third syllable receives secondary stress (Fitzgerald 1997). In this dissertation, I analyze only monosyllables and disyllables.

1.5.2.3 Sonority

The sonority of O'odham sounds is also an important factor in understanding the syllable structure discussed in this dissertation. Sonority is defined in (29) below:

(29) Sonority

Segment α is more sonorous than β, when α has greater intrinsic loudness in comparison to β.

Vowels, glides, liquids and nasals are referred to [+sonorant], whereas obstruents are [-sonorant]. The sonorous segments can be ordered hierarchically by the degree of their sonority. This is called the sonority hierarchy. Vowels are highest in the sonority hierarchy, then glides or semi-vowels, followed by liquids and nasals. Obstruents are lowest on the sonority scale. In the scale shown in (30), the most sonorous category [vowel] is numbered 5 with the number decreasing as the sonority of the sound category decreases (Selkirk 1984, Clements 1990, 1991).

(30) Sonority Hierarchy[13]

[+sonorous]	5	Vowels
	4	Glides
	3	Liquids
	2	Nasals
[-sonorous]	1	Obstruents

A consonant cluster generally cares about the sonority hierarchy in its allowable sequence of elements. Sonority increases towards the peak of the syllable, and decreases away from the peak. For example, in English, the monosyllabic word *trained* [trend] contains the sequence of [obstruent]-[liquid]-[vowel]-[nasal]-[obstruent]. The vowel is the peak of the syllable, and both segments next to the vowel are higher in sonority than are the segments on both edges. In other words, the sonority of the onset is upward or rising and the sonority of the coda is downward, or falling.

(31) Sonority Example

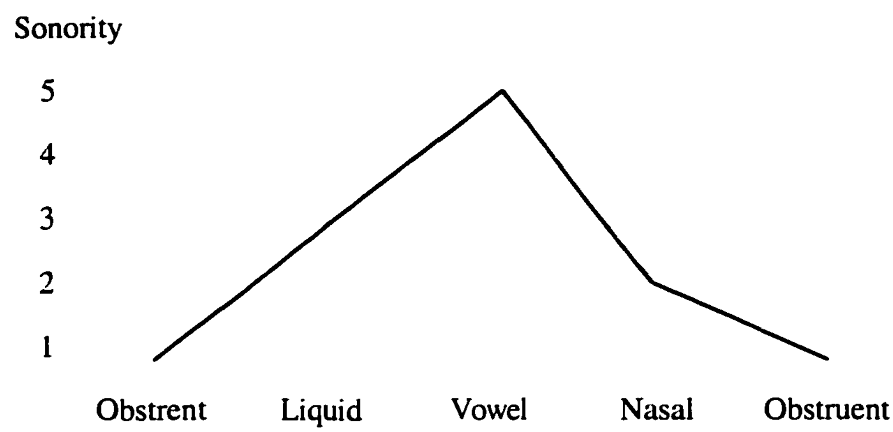
word *'trained'* [trend]

[obstruent]-[liquid]-[vowel]-[nasal]-[obstruent]

1 3 5 2 1

The same example is illustrated in a form of graph in (32) below.

(32) Sonority Example in Graph



In Tohono O'odham, the sonority can be more distinctly reduced to either [+sonorous] or [-sonorous]. In other words, the sonority hierarchy in O'odham is in two levels: [sonorant] or [obstruent]. The examples in (33) below show O'odham consonant clusters and the two-level construction. The discussion on sonority hierarchy in Chapter 2 uses this two-level system.

(33) O'odham Sonority in Consonant Clusters

a.	či**pk**	'worked, perfetive'	[obstruent][obstruent]
b.	pua**lt**	'door'	[sonorant][obstruent]

1.6 Summary and the Outline of the Dissertation

In this chapter, I have given an introduction to this dissertation. The purposes of this dissertation and background information about the O'odham language, as well as about

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[13] Among obstruents, fricatives are considered to be more sonorous than stops. Also, voiced segments are more sonorous than their voiceless counterparts. In O'odham, such sonority hierarchy within obstruents is ignored.

linguistics, were provided. I have explained three different aspects in linguistics to which my dissertation contributes: descriptive, theoretical and applied. I have provided background in phonological theory because the main focus is phonology and basic knowledge of this field is necessary to understand my analyses. I have also given an overview of the Tohono O'odham language and community. All of these sections will provide the reader with enough basic background to understand the following chapters.

In Chapter 2, basic syllable structure in Tohono O'odham is described. First I discuss the notion of the syllable and describe the internal structure of a syllable in O'odham. What is allowed and not allowed to comprise a syllable in O'odham is described. Then O'odham moraic structure is discussed. After a descriptive analysis of the O'odham syllable, the syllable structure in O'odham is analyzed in terms of Optimality Theory.

In Chapter 3, the syllable structure that is discussed in Chapter 2 is analyzed more thoroughly by looking at words and syllables with diphthongs. A description of O'odham diphthongs is provided first, then generalizations of diphthong patterns are given with respect to syllable weight. The Optimality Theoretic analysis follows. In the end of Chapter 3, I explore the weight of diphthongs in exceptionally stressed words.

Both Chapters 2 and 3 have aspects of descriptive and theoretical linguistics. Data shown in these two chapters are based on Mathiot's (1973) dictionary of Tohono O'odham supplemented by Saxton et. al. (1983). The data from Mathiot were electronically available from preliminary work on a Tohono O'odham online dictionary (Miyashita and Moll 1998). I used the programming language Perl to search the corpus and collect data.

In Chapter 4, phonological phenomena described and analyzed in Chapters 3 are examined with an acoustic experiment involving a native speaker and learners of O'odham. The chapter describes how diphthongs are pronounced by a native speaker and provide evidence that learners make errors in pronunciation. A statistical analysis is also given with the results of this experiment. I also attempt to give some suggestions in language education with respect to language maintenance for Tohono O'odham.

Finally, Chapter 5 gives a summary of this dissertation and a short discussion regarding linguistic study and language teaching and learning. I hope to contribute to descriptive and theoretical linguistics, as well as language maintenance, with this study.

CHAPTER 2: BASICS OF TOHONO O'ODHAM SYLLABLES

2.1 Introduction

In this chapter, the syllable and its structure in Tohono O'odham are discussed. First, motivations for the existence of syllables in Tohono O'odham are presented. Both non-phonological and phonological evidence is provided. Non-phonological reasons such as native speaker intuition provides evidence for the existence of syllables in O'odham, but it does not reveal specific syllabification or syllable internal structure. Phonological reasons, however, are able to provide an analysis of O'odham syllable structures. I use phonological evidence in order to illustrate O'odham syllable structure. What a syllable can consist of, such as the number of consonants in the beginning and ending of a syllable, is discussed. Second, I present the motivation for the existence of the mora in Tohono O'odham. Morpho-phonological evidence such as truncation is presented in order to support the moraic analysis. Third, both O'odham syllable structure and mora structure are analyzed in terms of Optimality Theory. While most OT articles deal with morpho-phonological phenomena or sound alternation, this chapter speaks strictly to the structure of O'odham syllables.

2.2 O'odham Syllables

In this section, I explore the evidence for syllables in O'odham. In general, syllables are countable units that consist of a string of sounds including one vocalic segment, or vowel (c.f. Clements and Keyser 1983). First, I provide motivation for the existence of syllables in Tohono O'odham using non-phonological support. The non-phonological support is native speakers' intuitions. Second, I provide evidence for syllables using phonological motivation: stress.

2.2.1 Non-phonological Factor: Intuition

Non-phonological evidence motivates syllables in Tohono O'odham. A syllable can be determined by speakers' intuition. Fitzgerald (1997) used speaker's intuition in order to identify stress in a word. This method, the tapping method, is carried out in the following manner. Speakers are all bilinguals in Tohono O'odham and English. They are trained how to do this tapping using English words, then transfer the task to Tohono O'odham. First, they begin by tapping every syllable of a word given. For example, for an O'odham word, *papadogakam* 'ones owning ducks', they 'tap out' all five syllables: *pa, pa, do, ga,* and *kam*, as shown below.

(1) **Tapping on All Syllables**

pa	pa	do	ga	kam
TAP	TAP	TAP	TAP	TAP

Next, they tap only one syllable once when they perceive stress in the word. This helps in determining primary stress. So the response will be, for instance, tapping only on the first syllable *pa* of ***papadogakam***.

(2) Tapping on Only One Syllable

pa	pa	do	ga	kam
TAP				

Participants are then asked to answer if they feel any other syllable should be tapped. They add a tap when they feel they should do so. An example of this process would include tapping the first syllable *pa* and the last syllable *kam* of *papadoga**kam***.

(3) Tapping on Two Syllables

pa	pa	do	ga	kam
TAP				TAP

This anticipates the identification of secondary stress, and the question is repeated. An example of this is tapping an additional syllable *do* in the *papa**do**gakam*, resulting in the three tap-outs, illustrated in (4).

(4) Tapping on Three Syllables

pa	pa	do	ga	kam
TAP		TAP		TAP

Finally, participants are given other tapping patterns that are expected to be wrong, and asked for a judgement to confirm their initial judgement. For instance, they are given two options such as the following:

(5) Comparison Between Right and Odd Tapping

a.	pa	pa	do	ga	kam
	TAP	TAP		TAP	
b.	pa	pa	do	ga	kam
	TAP		TAP		TAP

The example answer is represented in (5b). As a result, the stress assignment of *papadogakam* is characterized. The primary stress is on the first syllable, secondary stress is on the last syllable, and tertiary stress on the syllable in the middle. The representation results in *pápadògakàm*.

The tapping method presented above is useful for finding the stress pattern successfully. As a matter of fact, the method shows syllable-motivation in O'odham. As shown above, stress is assigned to a syllable. The first request for the speaker was to tap out every syllable.

(6) **Tapping on All Syllables**

pa	pa	do	ga	kam
TAP	TAP	TAP	TAP	TAP

This test uses speakers' intuition of syllables and indirectly shows that syllables do exist in the language. Syllables are assumed throughout this dissertation.

2.2.1.1 Intuitions and Syllables

It is important to mention the relationship between intuition and syllables. The number of syllables in a word may not easily be determined by the tapping method. That is, it is uncertain whether the unit they are tapping actually represents a syllable. The countable unit may differ depending on the language. It is possible for a language to have something other than a syllable as a countable unit. For example, a mora is a basic countable prosodic unit in Japanese rather than a syllable (Bekku 1977, Cole and Miyashita to appear, Kogure and Miyashita 2000). The following are haiku verses from Issa (7) and Basho (8). Haiku requires a fixed number of moras in each line. The first line must have five moras, the second line must have seven moras and the third line must have five moras. The syllable counts of the lines do not necessarily agree with the number of moras. For example, Issa's line (7a) contains five moras but the number of syllables is only four because the third syllable [gae] is bimoraic because of its diphthong [ae]. In the same manner, the line in (7b) contains seven moras but only six syllables because the second last syllable contains two moras with the coda consonant [s].

(7) Moras and Syllables in Haiku 1

a.		ya	se	gae	ru			'skinny frog'
	mora	μ	μ	$\mu\mu$	μ			
	syllable	σ	σ	σ	σ			
b.		ma	ke	ru	na	is	sa	'don't lose, I'
	mora	μ	μ	μ	μ	$\mu\mu$	μ	
	syllable	σ	σ	σ	σ	σ	σ	
c.		ko	re	ni	a	ri		'am right here'
	mora	μ	μ	μ	μ	μ		
	syllable	σ	σ	σ	σ	σ		

(Issa 1997)

Basho's haiku exhibits similar patterns. The line in (8b) contains seven moras but only six syllables because the first syllable is a long vowel, resulting in a bimoraic syllable. All lines contain the syllable [tsu̥] with the voiceless vowel [u̥]. These syllables are considered moraic.

(8) Moras and Syllables in Haiku 2

a.

	ma	tsu̥	shi̥	ma	ya	'Matsushima (island)'
mora	μ	μ	μ	μ	μ	
syllable	σ	σ	σ	σ	σ	

b.

	aa	ma	tsu̥	shi̥	ma	ya	'Oh, Matsushima'
mora	μμ	μ	μ	μ	μ	μ	
syllable	σ	σ	σ	σ	σ	σ	

c.

	ma	tsu̥	shi̥	ma	ya	'Matsushima'
mora	μ	μ	μ	μ	μ	
syllable	σ	σ	σ	σ	σ	

(Bassho in Yamamoto 1974)

As shown above, the basic prosodic unit or the countable unit in Japanese is the mora and not the syllable.

There is no literature that points to a basic prosodic unit in O'odham. Most O'odham studies assume syllables as the basic countable unit. In other words, although the tapping method suggests that the tapped group of sounds is a syllable, the basic unit of O'odham might not be the syllable, rather possibly the mora or something else. The O'odham basic prosodic unit needs further study. In my dissertation, however, I adopt the results of Fitzgerald (1997) and assume that these tapped elements are syllables in O'odham.

2.2.2 Phonological Factor: Stress

In addition to the non-phonological evidence for the syllable in O'odham as shown in the above section, there is also phonological evidence for O'odham syllables. In this section, phonological evidence for the syllable in the O'odham language is presented. Stress, which is described below, provides syllable motivation. In general, stress is a supra-phonological element assigned to the peak of a syllable. The contrast between a stressed syllable and an unstressed syllable is realized by the relative degree of prominence between adjacent syllables. Stress is what is heard as the salient acoustic signal in a word, demarcating it from other syllables. The phonetic properties of stress are *amplitude* (loudness), *duration* (length), *frequency* (pitch), or any combination of two or all of them (Lehiste 1970).

Amplitude is the loudness of a syllable relative to that of the neighboring syllables. The English word *attend* [ətɛ́nd] has two syllables, [ə] and [tɛ́nd]. The second syllable is pronounced more loudly than the first syllable. This reflects the fact that the second syllable receives stress and the first syllable is unstressed.

(9) Engliss Stress

attend	
[ə	tέnd][1]
unstressed	stressed
	louder

The second phonetic property that accompanies the stress assignment is duration. Duration is the time length of the pronunciation. In Italian, the default stress falls onto the penultimate syllable (the second from the end), and the pronunciation of the stressed syllable is longer than that of other syllables in the word. This is true in other languages such as Spanish and Russian. Their stressed syllables are pronounced with longer duration than unstressed syllables.

The third phonetic property is frequency, which is the pitch of the pronounced segment. In general, a stressed syllable receives higher pitch than an unstressed syllable.

These three phonetic features tend to co-occur. For example, English stressed syllables are accompanied by higher pitch, higher amplitude and longer duration. Furthermore, only one or two of these acoustic properties alone can serve as the prosodic cue(s) for native speakers to perceive stress in language. Stress is perceived when one

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[1] The correct phonetic transcription would be [ətɛ̃́:nd], with vowel nasalization and lengthening due to the English phonological rule that a vowel is nasalized before a nasal consonant and a vowel is lengthened before a voiced consonant. I simplified the representation above because the point was only to illustrate stress and not to give the exact phonetic transcription.

hears a peak in the sound string. In other words, stress is assigned to the peak of a syllable, illustrating that syllables are motivated by stress.

The first syllable of O'odham words receive stress (Saxton et. al. 1983, Fitzgerald 1997). By way of extension, the fact that O'odham syllables can carry stress supports the theoretical existence of O'odham syllables. Further examples in support of this position follow.

2.2.3 Summary

I have shown the motivations of syllables in O'odham. Intuition motivates syllables, as demonstrated by native speaker syllable tapping. The tapping method is effective for stress finding, and supports syllable structure. The basic prosodic unit, however, does not determine syllable boundaries.[2]

Stress is also supported by the existence of syllables. O'odham words have stress, thus the argument can be made that syllables exist. However, this does not specify the boundary of the syllables. The next section explores this question by looking at the internal structure of syllables in Tohono O'odham.[3]

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[2] The intuition of syllable boundaries sometimes differs from speaker to speaker. For example, an English word such as balance is notorious (Cutler et al. 1986) for having a segment known as ambisyllabic. The consonant [l] in balance is not clearly determined as either the coda of the first syllable or onset of the second syllable.

[3] In addition, O'odham poetry exists (Fitzgerald 1998), and this may serve as further non-phonological evidence of syllable existence.

2.3 Syllable Structure

In this section, the syllable structure of Tohono O'odham is presented. It illustrates how words are syllabified, which is basic but important knowledge regarding theoretical phonology. In the following sections, the syllable structures of O'odham are examined. An O'odham syllable exhibits a unique phonotactic structure consisting of restrictions in terms of possible onsets and codas. First, I present a description of onset in O'odham, then coda.

2.3.1 Onset

In this section, the onset of syllables in O'odham is described. Onset is the consonant or consonants that appear at the beginning of a syllable followed by the peak of the syllable. The kind of consonant that can appear as onset, the number of consonants that can appear in the onset position, as well as the requirement for onset, in O'odham are described. As shown in (10) below, any O'odham consonant can be an onset. No words begin with the retroflex /ḍ/ and velar nasal /ŋ/, but these consonants do appear in words inter-vocalically.

(10) Consonants in Onset

a.	/ʔ/	ʔali	'child'
b.	/b/	**ban**	'coyote'
c.	/p/	**paan**	'bread'
d.	/č/	**čɨggia**	'fighting'

e.	/ǰ/	ǰiʔɨ	'mother'
f.	/h/	hikc	'cut'
g.	/k/	kii	'house'
h.	/g/	gatwid	'shooting'
i.	/t/	toki	'cotton'
j.	/d/	daha	'sit'
k.	/m/	miisa	'table'
l.	/n/	nai	'make fire'
m.	/ñ/	ñɨid	'seeing'
n.	/l/	laabis	'pencil'
o.	/s/	siʔi	'suck'
p.	/ṣ/	ṣaamud	'herding'
q.	/w/	woʔo	'lay'
r.	/y/	yaanda	'a tire'
s.	/ḍ/	unattested in initial position[4]	
t.	/ŋ/	unattested in initial position	

In short, any phonemic consonant except for /ŋ/ can be in the onset position. Also, the phoneme [ḍ] does not appear in a word-initial position.

2.3.1.1 Onset Requirement

There are two important requirements for Tohono O'odham onsets: i) A syllable must have an onset, and ii) an onset must be simple. The data in (11) below show that O'odham words always begin with onsets, fulfilling the first requirement. Without one, the words become ungrammatical as shown below with asterisks.

(11) O'odham words must have Onset

a.	ʔali	'child'	* ali
b.	ban	'coyote'	* an
c.	paan	'bread'	* aan
d.	hikc	'cut'	* ikc
e.	gatwid	'shooting'	*atwid
f.	nai	'make fire'	* ai
g.	woʔo	'lay'	* oʔo

[4] This retroflex consonant appears inter-vocalically as in [maḍaǰ] 'child of a female'. It also occurs as a variation of [ḷ], which is also a retroflex in the O'odham phonemic inventory.

The second requirement for onset is described below. All O'odham words begin with a single consonant, but never with a consonant cluster.[5] As shown in (12) below, word-initial consonants are always single. When an onset contains more than one consonant, it is ungrammatical.

(12) Single Consonants in Onset

a.	ban	'coyote'	* kban
b.	čɨggia	'fighting'	* bčɨggia
c.	hikč	'cut'	*phikč
d.	kii	'house'	* dkii
e.	gatwid	'shooting'	* dgatwid

As, shown above, the onset must consist of only one consonant.

In summary, the onset generalizations in Tohono O'odham are outlined in (13) below.

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[5] I am not talking about grammatical prefixes such as *s*- or *ñ*- here. There are prefixes that create initial consonant clusters. They are often pronounced with a schwa insertion. (The consonant [s] seems to be okay to be pronounced without epenthesis by the nature of its phonetic features.)

(13) O'odham Onset Generalization

a. O'odham syllables must have onset.

d. An O'odham onset must be simple (only one consonant).

These generalizations are assumed in subsequent sections and chapters.

Based on the generalization above, word *mimsa* 'tables' is correctly syllabified as in (14a). (14b) and (14c) are incorrectly syllabified because the second syllable in (14b) has complex onset and the last syllable in (14c) has no onset. This type of syllabification is analyzed in terms of OT in section 2.5.

(14) Correctly and Incorrectly Syllabified Examples

a. mim.sa √

b. *mi.msa (incorrect)

c. *mims.a (incorrect)

2.3.2 Coda

In this section, a description of Tohono O'odham coda is presented. A coda is th closing consonant (or consonants) in a syllable. In general, a syllable can be categorized into two groups depending on the existence (or lack) of a coda. If a syllable consists of only the onset followed by a vowel (CV), then there is no coda in the syllable, and the syllable is called an open syllable as illustrated in (15). If a syllable consists of an onset followed by a vowel, which is also followed by one or more consonants (CVC), then the syllable is called a closed syllable, and the last consonant is considered the coda of the syllable. This relationship is demonstrated in (16). O'odham words can end with a vowel, or a consonant. As shown in (16) below, some words contain a consonant such as *ban* in (16b).

(15) Open and Closed Syllables

a.	CV	open syllable	has no coda
b.	CVC	closed syllable	has a coda

(16) Example Words with Codas

		Coda Consonant	Gloss	Class
a.	kii	0	'house'	Open
b.	ban	1	'coyote'	Closed

In short, O'odham syllables can be open class or closed class because a syllable can have a coda, but need not. There is no requirement that a syllable must have a coda, like the onset requirement as shown in the section about onset. Next, the kinds of consonants that can appear in a coda and the number of consonants allowed in coda position in O'odham are described.

2.3.2.1 Coda with Various Consonants

In this section, the kinds of consonants that can exist in a Tohono O'odham coda are examined. I provide examples of codas in monosyllables (a), codas in the first syllable of disyllables (b), and codas in the second syllable of disyllables (c).

(17) Coda Position

a.	**CVC**	monosyllable
b.	**CVCσ**	first syllable of disyllable
c.	**σCVC**	second syllable of disyllable

The following data show O'odham codas in monosyllabic words. All consonants appear as codas except [y] and glottal consonants [ʔ] and [h].

(18) Coda in Monosyllables[6]

a.	/b/	baa**b**	'grandfather on mother's side'
b.	/p/	ʔɨɨ**p**	'another'
c.	/t/	bi**t**	'dirt'

[6] [ŋ] is always followed by [g] as in [ta:ŋgi] 'tank' and [ča:ŋgo] 'monkey'. Since it is predictable when this [N] occurs, there is no need to make [ŋ] a separate symbol. However, it is difficult say that this is a allophone of the nasal [n]. This velar nasal occurs followed by a velar sound only within Spanish loan words. The traditional O'odham [n] before a velar consonant is unassimilated. Therefore, some O'odham linguistis list [N] as a phoneme and some does not. Although I included this velar-nasal in the inventory in Chapter 1, I treat this [N] more like an allophone of a nasal and do not list it in this chapter. (p.c. Hale)

d.	/d/	daa**d**	'senior aunt on mother's side'
e.	/s/	has	'what (abstract)'
f.	/č/	huu**č**	'fingernail'
g.	/ǰ/	čɨo**ǰ**	'boy'
h.	/ḍ/	hu**ḍ**	'came down'
i.	/l/	haa**l**	'squash'
j.	/ṣ/	biiṣ	'to corner obj.'
k.	/k/	daa**k**	'nose'
l.	/g/	heg	'that'
m.	/w/	gɨw	'to hit obj.'
n.	/m/	hi**m**	'walking'
o.	/n/	ba**n**	'coyote'
p.	/ñ/	či**ñ**	'mouth'
q.	/y/	unattested	
r.	/ʔ/	unattested	
s.	/h/	unattested	

Next, codas in the second syllable of disyllabic words are shown in the data (19) below. All but the glide [y] and the glottal consonants [ʔ] and [h] can appear in this position.

(19) **Coda in Second Syllable of Disyllables.**

a.	/b/	wasi**b**	'liquid in a container with a large opening'
b.	/p/	daiwu**p**	'to arrive on foot'
c.	/t/	kali**t**	'wagon'
d.	/d/	ʔaagi**d**	'telling'
e.	/s/	laabis	'pencil'
f.	/č/	baʔi**č**	'in front of'
g.	/ǰ/	ʔaǰi**ǰ**	'thin, narrow'
h.	/ḍ/	daiku**ḍ**	'chair'
i.	/l/	čihi**l**	'scissors'
j.	/ṣ/	čipoiṣ	'to make several thrusts at obj. with a sharp thing'
k.	/k/	giʔi**k**	'four'
l.	/g/	doʔag	'mountain'
m.	/w/	kɨli**w**	'to shuck obj. such as corn'
n.	/m/	judu**m**	'bear'
o.	/n/	čipka**n**	'working'
p.	/ñ/	haiwa**ñ**	'cow'
q.	/y/	unattested	

r. /ʔ/ unattested

s. /h/ unattested

O'odham allows all phonemes except [y] and glottal consonants [ʔ] and [h] in codas. There is no difference between this type of consonant and those appearing in word final position. In the following section, I explore consonant clusters in coda position.

2.3.2.2 Consonant Clusters in Codas

The number of consonants allowed in coda position also varies from language to language. For instance, a language like Japanese restricts the number of consonants in a coda position to one (Ito et. al. 1995). A nasal consonant [n] as in *san* "three" and the first element of geminate [k] as in *sakka* "writer" are allowed to appear as coda in Japanese. If there is a violation of such a restriction, the result is ungrammatical. For example, *san* is a well-formed word but [sat] is an ill-formed one. Similarly, [sakka] is well-formed, but [satka] is not because the [t] does not form a geminate with the following [k]. On the other hand, a language like English allows up to four consonants within one coda position. Two famous examples are *sixths* [sɪksθs] and *texts* [tɛksts].

It has not been established how many consonants are allowed to appear in one coda position in the literature on Tohono O'odham phonology. However, up to three coda consonants are attested. First, I examine word final clusters and then word medial clusters. The data below show consonant clusters consisting of two segments (double) as illustrated in (20) and three segments (triple), as (21) demonstrates.

(20) Monosyllable: Double consonants in Word-Final Position

a. hi**kč** 'cut (perf.)'

b. kuu**bs** 'smoke'

c. sii**ṣp** 'pining'

d. ṣuu**ṣk** 'shoes'

e. pua**lt** 'door'

f. paa**nt** 'making bread'

g. ʔo**ks** 'old lady'

h. bi**sč** 'sneezing'

i. bi**dṣ** 'get muddy'

j. ku**pṣ** 'to close one's eye'

k. kuu**tṣ** 'to heat grease wood on coals'

l. maa**mṣ** 'castor beans'

m. hɨ**wk** 'to get cold'

(21) Polysyllable: Double Consonants in Word-final Position

a. nola**wt** 'buying'

b. ṣopo**lk** 'short'

c. hita**sp** 'five'

d. ba?i**wč** 'to get ahead of obj.'

(22) Monosyllable: Triple Consonants in Coda

a. hi**kčk** 'cutting'

b. gɨ**wṣč** 'to have obj. trapped'

c. gɨwṣp 'to freeze'

(23) Polysyllable: Triple Consonants in Coda

a. sə-bamu**stk** 'to be good tempered'

b. dada**gṣp** 'to put hands somewhere'

c. tooto**nck** 'to be kneeling down'

As can be seen in the data, an O'odham coda position appears to have at most three consonants. Note that although most of the words above are monomorphemic, some words with consonant clusters are not. For instance, O'odham often exhibits single consonant suffixes such as [-t] 'to make something' (Zepeda 1984). A suffix such as the [-t] in [paant] 'making bread' transforms a noun into a verb with the meaning of 'making something that the noun refers to.' This results in clusters in the coda position. In short, O'odham codas hold up to three consonants in one word final position.

2.3.4 Word-Medial Consonants

In this section, a description of word-medial consonants is presented. A word medial consonant is one that appears between the peaks of two syllables. Such a consonant could be either the onset or the coda of a syllable, or both. Since O'odham must have an onset consonant, at least one consonant always appears word-medially in a disyllable word. When there is a polysyllable with single medial-consonant, the consonant can be determined as the onset of the following vowel. This can also be supported by the fact that an O'odham syllable does not need a coda.

Since O'odham syllables must have a single consonant as their onset and may have up to three coda consonants, it is predicted that they will have one to four word-medial consonants. The following data (24) and (25) show examples of word-medial consonant positions:

(24) Word-Medial Consonant: One (No Coda + Onset)

a.	ka.lit	'wagon'
b.	ʔaa.gid	'telling'
c.	laa.bis	'pencil'
d.	ba.ʔič	'in front of'
f.	ʔa.ǰiǰ	'thin, narrow'
g.	dai.kuḍ	'chair'

(25) Word-Medial Consonant: Two (One coda consonant + Onset)

a. ʔii**b.hai** 'prickly pair'

b. či**p.kan** 'working'

c. ga**t.wid** 'shooting'

d. bi**d.pig** 'to take the mud off obj.'

f. či**č**.wi 'playing'

g. ǰi**ǰ.ka** 'to taste obj. repeatedly'

The next data set shows double and triple consonant clusters in word-medial position (the coda of the first syllable in disyllable words). The number of the consonant cluster in (26) is actually two in stead of three.

(26) Word-Medial: Three (Two coda consonants + Onset)

a. we**st.maan** 'ten'

b. ga**gt.wid** 'shooting pl.'

c. kii**čk.wa** 'kicked'

d. mai**st.la** 'teacher'

(27) **Word-Medial: Four (Three coda consonants + Onset)**

a. **tonck.wa** 'to knock obj. down'

b. **giwpk.dag** 'somebody's power'

2.3.5 Summary

O'odham syllables must have onsets, and the onset is restricted to a single consonant. No consonant cluster is allowed in the onset position. On the other hand, coda is more flexible. Codas are optional, and if there is a coda, up to three consonants are allowed to appear in one coda position.

2.3.6 Sonority Hierarchy in Consonant Clusters

Now that the number of consonants in a coda position has been defined, let us turn to the quality of consonants. As shown above, onsets are required in O'odham, but the number of segments in the onset position is restricted to only one consonant. On the other hand, codas are not required in O'odham syllables, but the number of segments in this position is allowed to be up to three consonants. However, the arrangement of consonant clusters in coda position seems to have restriction via Sonority (Selkirk 1984, Clements 1990,1991). As described in Chapter 1, O'odham sonority is a simple two scale consisting of obstruent and sonorant.

Since Tohono O'odham restricts consonant clusters to coda positions, only coda is relevant in examining sonority hierarchy. In coda position, sonority is never rising, rather, it is falling or flat with obstruents. There are few cases of monomorphemic words with coda consonant clusters. The examples given in (28) and (29) are monomorphemic words.

(28) Falling Sonority

a.	maa**mṣ**	'an animal tick'	[S][O]
b.	pua**lt**	'door'	[S][O]
c.	ṣopo**lk**	'short'	[S][O]

(29) Flat Sonority

a.	bi**sč**	'sneezing perf.'	[O][O]
b.	hɨta**sp**	'five'	[O][O]
c.	sii**ṣp**	'pinning'	[O][O]
d.	ṣuu**ṣk**	'shoes'	[O][O]
e.	ʔo**ks**	'old lady'	[O][O]

2.3.6.1 Sonority in Polymorphemic Words

O'odham polymorphemic words exhibit the same sonority hierarchy, as monomorphemic. again, this is either falling or flat as shown in (30) and (31) below.

(30) Polymorphemic Falling

a.	**paan-t**	'making bread'	[S][O]
b.	**hɨw-k**	'to become chilled'	[S][O]

(31) Polymorphemic Flat

a.	**kuub-s**	'smoke n.'	[O][O]
b.	**kup-ṣ**	'to close eye(s)'	[O][O]
c.	**bid-ṣ**	'get muddy'	[O][O]

Regardless of the monomorphemic or polymorphemic status of a word, O'odham codas show falling or flat obstruents in the sonority hierarchy of their consonant clusters. Thus, it is concluded that rising sonority does not appear in coda. Of the four possibilities in sonority scales shown in (32) below, O'odham allows two. The sequence in (32a) does not appear. The sequence (32b) is possible because they are flat of obstruents. (32c) is fine because it is falling. (32d) fails because it is rising.

(32) Possible Sonority Scale

a.	* [S][S]	flat
b.	[O][O]	flat
c.	[S][O]	falling
d.	* [O][S]	rising

From the pattern given above, the occurrence of consonant clusters in O'odham coda positions is generalized into one form, illustrated in (33):

(33) Generalized O'odham Coda Cluster

*X[S] or X[O]

This means that a sonorant cannot follow another consonant. Among the two variations of the representation given in (33) above, only one of them is chosen in section below.

2.3.6.2 Sonority Hierarchy of Triple Consonants

As well as double consonant clusters, falling or flat sonority is respected in triple consonants. The examples are shown in (34) and (35).

(34) Falling

a.	gɨwsp̣	'to trap obj.'	[S][O][O]
b.	sə-kawpk	'hard, fifficult'	[S][O][O]
c.	kamṣp	'to put obj. in one's mouth'	[S][O][O]
d.	mamtk	'palm of the hand'	[S][O][O]

(35) Obstruent Flat

a.	hikčk	'cutting'	[O][O][O]
b.	sə-kuustk	'to be able to endure thirst'	[O][O][O]
c.	waapkč	'to have obj. on'	[O][O][O]
d.	sə-dadpk	'to be smooth'	[O][O][O]

All of the examples are either a combination of a sonorant followed by two obstruents or all obstruents. Based on this fact, possible O'odham sonority combinations are given in (36):

(36) Sonority Combinations

a. * [S][S][S]

b. * [S][S][O]

c. * [S][O][S]

d. [S][O][O]

e. * [O][O][S]

f. [O][O][O]

g. * [O][S][S]

h. * [O][S][O]

Note that the incorrect combinations always contain the sequence of X[S]. The pattern of double consonant clusters had choices of *X[S] or X[O]. Triple consonant clusters can also be generalized as *X[S]. However, X[O] cannot be the form of the generalization in this case because it can potentially include incorrect forms such as those represented by (36b), (36c), (36e), and (36h). We can see then, that O'odham possible consonant cluster sequences are captured with the constraint shown in (37):

(37) O'odham Consonant Cluster:

*X[S]

The last element of the cluster is always an obstruent. For a consonant cluster that consists of two consonants, the first element is either sonorant or obstruent consonant, and an obstruent consonant is attached. For the triple consonants, an obstruent consonant is added to the double cluster that is already formed.

2.3.6.3 Sonority in Word-Medial Clusters

Sonority only matters with the coda consonant cluster. So when a coda is followed by an onset of the next syllable, the cluster can be followed by a sonorant consonant. As shown in (38) to (40) below, the sonorant consonant can follow another consonant as opposed to the generalization made in the coda clusters. This is because the sonorant consonant is not a part of the coda.

(38) Word-Medial Consonant: Two (One coda consonant + Onset)

a. **čip.kan** 'working'

b. **gat.wid** 'shooting'

(39) Word-Medial: Three (Two coda consonants + Onset)

a. **west.maam** 'ten'

b. **maist.la** 'teacher'

(40) Word-Medial: Four (Three coda consonants + Onset)

a. **tonck.wa** 'to knock obj. down'

b. **gewpk.dag** 'someone's power'

2.3.6.4 Summary of Sonority Hierarchy

We have established that coda consonant clusters respect sonority in O'odham. Furthermore, when a coda consists of two consonants, the sonority in a sequence must be falling or obstruent-flat. However, when a coda consists of more than two consonants (three or four), the sonority sequence is such that obstruent is added to obstruent or obstruent-flat. There is no sequence in which a consonant is followed by a sonorant.

2.3.7 Summary of Descriptive O'odham Syllables

I have described the syllable structure of Tohono O'odham in the preceding sections. O'odham syllables so far are generalized as follows in (41):

(41) Generalization of O'odham Syllables

a. must have an onset

b. can have a coda

c. consonant clusters are allowed in a coda

d. coda holds one, two or three consonants

e. consonant clusters have no sonorant followed by another consonant in a syllable.

These generalizations are analyzed in terms of OT in section 2.5. Before the OT analysis, however, it is necessary to decide O'odham moraic structure in the next section.

2.4 O'odham Moras

Moraic structure is a very important component in O'odham phonology. In this section, a discussion of O'odham moras is presented. As discussed in the introductory chapter, mora is a phonological unit that is smaller than a syllable. Examples of internal syllable structure regarding moras are shown below. The two monosyllables shown in

(42a) and (42b) are different in terms of their moraic structures. (42a) has only one mora in a syllable while (42b) contains two of them.

(42) Moras

a. monomoraic	b. bimoraic
[a]	[aa]
σ	σ
|	/\
μ	μμ
|	V
a	a

A syllable with one mora is called a monomoraic syllable –a, and it may look like *a, ka, ni, mo, ski*, etc. A bimoraic syllable, which contains two moras, may look like *aa, kua, skoa, lee*, etc. The following sections present motivation for moras in O'odham.

2.4.1 Morpho-phonological Mora Motivation

The presence of moras is usually motivated when languages possess a phonemic distinction between short vowels and long vowels. For example, the Japanese words listed in (43) show such a distinction. The only difference between these pair members is the vowel length.

(43) Minimal Pairs

a.	obasan	'aunt'	vs.	obaasan	'grandmother'
b.	ojisan	'uncle'	vs.	ojiisan	'grandfather'

The vowel lengths in the preceding examples are phonemically significant because they makes distinctions in word meaning. The phonological difference between the two vowels lies in the number of moras they contain. In (43a), the two words differ in the vowel length of the second syllable *ba* and *baa*. With the short vowel [a], the word means 'aunt', and with the long vowel [aa], it means 'grandmother'. This lexical difference is well explained by the notion of mora.

2.4.1.1 Tohono O'odham Moras

Similarly, Tohono O'odham exhibits meaning differentiation via minimal pairs consisting of short and long vowels, as shown in (44).

(44) O'odham Minimal Pair[7]

a. hik 'navel' vs. hiik 'cut'

As I described in section 2.4.1, the lexical differentiation via vowel length variation motivates mora. In this sense, Tohono O'odham respects moras. I assume mora in

O'odham description and analysis, with the use of mora explained in the following sections.

2.4.1.2 Reduplication and Moras

Reduplication also supports the claim that O'odham is sensitive to mora, as demonstrated in this section. First, I describe the pattern of reduplication in Tohono O'odham, which manifests itself as a prefix to a base form (Hill and Zepeda 1998), as illustrated in (45).

(45) Reduplication

RED+base

The form which reduplicants take is not fully understood in O'odham prosodic phonology. However, three different types formations are presented below. First, some forms reduplicate the first consonant and vowel of the base, as seen in (46).

(46) CV → CV Reduplicant

	Base		Reduplicated	
a.	him	'walking'	hihim	'walking' (subject plural)
b.	gogs	'dog'	gogogs	'dogs'

---

[7] O'odham does not have many minimal pairs with a vowel length variation. The example above is the only one I am able to provide.

In the second form, the reduplicant copies the first syllable of the base but the vowel is lengthened as (47) demonstrates.

(47) CV → CVV Reduplicant

	Base		Reduplicated	
a.	ban	'coyote'	baaban	'coyotes'
b.	nowi̥	'hand'	noonowi̥	'hands'
c.	maḍ	'child'	maamaḍ	'children'

In the third instance, the first syllable of the base, which has a long vowel, is copied and attached but the vowel is shortened, as is illustrated in (48).

(48) CVV → CV

	Base		Reduplicated	
a.	maagina	'car'	mamagina	'cars'
b.	toonk	'hill'	totonk	'hills'
c.	toobi̥	'rabbit'	totobi̥	rabbits'

In a fourth scenario, the first syllable of the base, which contains a long vowel, is copied and attached to the base while the vowel stays long, as (49) demonstrates.

(49) CVV → CVV

	Base		Reduplicated	
a.	toon	'knee'	tooton	'knees'
b.	taaḍ	'foot'	taataḍ	'feet'

The reasons for the appearance of these variations of reduplicants are not yet clearly accounted for.[8] However, the appearance of a base form within the reduplicated form, as seen in (48) and (49) shows some important facts regarding O'odham moras. Furthermore, (50) illustrates, the term *base* means the singular form as in (50a). *Reduplicant* means the prefix that is reduplicated from the *base* and attached to the base to form a plural representation. *Base form in the reduplicated form* means the part that is the base without the reduplicant prefix. Examples of this are shown in (50) with the word *toonk* 'hill,' the base being *toonk* as in (50a). The *reduplicant* is *too,* as indicated by italicization in (50b), with the *base in reduplicated form* being the bolded part, *tonk*, as is also shown in (50b).

[8] Hill and Zepeda (1998) claim that long-vowel noun reduplication functions as a noun classifier.

(50) Base, Reduplicant and Base in Reduplicated Form

a.	toonk	'hill'	singluer, base form
b.	*too***tonk**	'hills'	plural, reduplicated form

When the base has a long vowel in its first syllable, the part copied is the syllable with a long vowel. The reduplicated form loses the long vowel which always surfaces as a short vowel. The word *toonk* 'knee reduplicates into *tootonk* 'knees'. The word reduplicates the first syllable [too]. The reduplicant keeps the long vowel [oo]. The reduplicant [to] is attached to the base *toonk*. However, the result of this reduplication is not *tootoonk* with the reduplicant and the base form. The base form *toonk* is reduced into *tonk* when the reduplicant is attached in front of the word.

(51) Reduplication

a.	m**áa**gina	'car'	mám**a**gina	* mámaagina
b.	t**óo**nk	'hill'	tóot**o**nk	* toótoonk
c.	t**óo**bi̥	'rabbit'	tót**o**bi̥	* tótoobi̥
d.	t**óo**n	'knee'	tóot**o**n	* tóotoon
e.	t**áa**ḍ	'foot'	táat**a**ḍ	* táataaḍ

When the vowel in the base is not reduced, the reduplicated form is incorrect. The base has to have a short vowel instead of a long vowel. The stress falls onto the initial syllable in O'odham, so the first syllable of the base forms receives stress and the reduplicants receive stress in reduplicated forms. In other words, stress is shifted to the prefix, and the first syllable of the base in reduplication is no longer in the initial position. As a result, the first syllable of the base of reduplication is in the unstressed position. The syllable is not allowed to stay long. In other words, the long vowel is shortened because of the requirement of the unstressed position: unstressed position must not be heavy. The number of moras is restricted to one in unstressed position. Thus, the reduplication process also tells us about the sensitivity to mora in Tohono O'odham.

2.4.1.3 Word Minimality

Word Minimality supports that Tohono O'odham is sensitive to moras. Word Minimality states that a content word must have at least two moras. A content word is a non-functional morpheme. Prepositions/postpositions and articles are not content words, as proposed in (52).

(52) Word Minimality

A content word must have at least two moras.

The data in (53) show that O'odham minimal words are always bimoraic and never monomoraic.

(53) Minimal Words

a.	kaa	'hearing'	* ka
b.	ʔoo	'back'	* ʔo
c.	čuk	'black'	* ču
d.	ʔaǰ	'narrow'	* ʔa

Minimal words consist of either an open syllable with a long vowel or a closed syllable with a short vowel. The former holds two moras because the vowel is long as shown in (54):

(54) Open Syllable with a Long Vowel

```
  kaa
  / |
 C  V
    |
    μμ
```

The latter is bimoraic because the coda can carry a mora as shown in (55).

(55) Closed Syllable with a Short Vowel

```
 ?aǰ
 /|\
C V C
  | |
  μ μ
```

Tohono O'odham words with only one mora do not occur because it has been demonstrated that they must have at least two moras. Thus, bimoraic Word Minimality is a core requirement in O'odham words.

2.4.1.4 Coda Not Necessarily Moraic

Non initial syllables can be claimed not to be heavy. The existence of a coda in such a syllable position does not make it heavy. This is supported by the following facts. Since O'odham words must be at least bimoraic, a monosyllabic word with a short vowel followed by a coda must be bimoraic. Therefore, the coda in such a word must be moraic. However, codas are not moraic in other positions. Consider the following. Heavy vowels appear only in stressed position. For example, loan words from Spanish reveal this moraless coda. A CVCVCCVC word such as *hemajkam* [hímaǰkam] 'person' does not attract stress in the second position, although a CVCVVCV word such as *asu:ga* [asúuga] 'sugar' does. We can say that this is because the CVC is not heavy. Therefore, we must conclude that a Tohono O'odham coda is not moraic unless it needs to be.[9]

---

[9] However, a coda is analyzed as moraic in a CVC word due to the Word Minimality requirement. This is discussed later.

2.4.1.5 Truncation and Word Minimality

Truncation also provides evidence of moras in O'odham, and shows how Word Minimality is respected. Truncation is a morphological phenomenon in which a part of a word is deleted. In Tohono O'odham, this phenomenon occurs in order to mark a verb perfective. A perfective verb is formed from an imperfective verb by truncating the last consonant segment. As shown in (56) below, perfective *maa* 'gave (56a) is formed by dropping the last consonant segment [k] of the imperfective form *maak* 'giving'. In the same way, *hiik* 'cutting,' *ṣoom* 'stop burning,' *wakon* 'washing,' *golon* 'raking,' and *hihid* 'blowing' also lose their last segment to form the perfective aspect.[10]

(56) Truncation[11]

	Imperfective		Perfective	
a.	máak	'giving'	máa	'gave'
b.	híik	'cutting'	híi	'cut'
c.	ṣóom	'stop burning'	ṣóo	'stopped burning'
d.	wákon	'washing'	wáko	'washed'

[10] The preceding vowel is also dropped when the vowel is high and its preceding (remaining final consonant) is coronal (Fitzgerald and Fountain 1996).

[11] Only consonant-final verbs undergo this type of truncation. Vowel final verbs are usually disyllables with the two identical vowels separated by a glottal stop, such as *siʔi* 'sucking'. Such verbs' perfectives are formed by deleting the glottal stop consonant. e.g. *sii* 'sucked.' Others like *cicwi* 'playing' do not undergo truncation.

e.	gólon	'raking'	gólo	'raked'
f.	híhid	'blowing'	híhi	'blew'
g.	híhidoḍ	'cooking'	híhido	'cooked'

Given the basic concept of Tohono O'odham truncation, we can examine how this morphological phenomenon supports mora in the language. Let us look at the truncation of a closed syllable with a short vowel. A CVC syllable such as *him* 'walking' is an imperfective form. This undergoes truncation and deletes the last consonant segment [m]. However, it does not surface as **hi*, rather, it surfaces as *hii* due to vowel lengthening. Examples of this type are shown in (57).

(57) CVC Truncation

	Imperfective		Perfective	
a.	hí**m**	'walking'	híi	'walked'
b.	mí**d**	'running'	míi	'ran'
c.	hú**g**	'ending'	húu	'ended'
d.	ʔó**ḍ**	'gathering'	ʔóo	'gathered'

This process is known as Compensatory Lengthening (Hayes 1989). As shown in (58), when a segmental deletion occurs and when the deleted segment was moraic, the mora remains and the preceding vowel is lengthened in order to maintain the original moraicity.[12]

(58) Compensatory Lengthening

```
CVC      CV      CV
 ||      |       |\
 μμ      μμ      μμ
```

The examples show that the deletion of a segment occurs independently from the mora status. The duration is usually explained by the use of a mora. As mentioned in the introduction, a vowel is short when it contains one mora and long when it contains two moras (Hayes 1989). As shown in (59), even though the segment [m] in the word *him* is deleted, the mora that was associated to the deleted [m] stays, and the preceding vowel is lengthened in order for the mora to be associated with the lengthened vowel.

(59) Truncation Example

him 'walking'[13]

```
him         hi          hi
 ||   ->    |     ->    |\
 μμ         μμ          μμ
```

[12] Compensatory Lengthening in truncation is seen only in monosyllables with a short vowel.
[13] Although the coda here is presented as moraic, Tohono O'odham coda in general is not moraic. A word like *gook* 'two' appears, and this coda consonant [k] seems to be moraic to the common understanding of mora. However, it also shows that the word without the coda is already heavy for having a long vowel [oo]. The coda does not have to be moraic to satisfy the Word Minimality. The speculation that the coda being moraic to this type of word (e.g. gook) results in a supra-heavy coda. However, a such notion is not necessary.

Vowel lengthening occurs to satisfy an important property that is required in Tohono O'odham. The results of the truncation of CVC must have a long vowel to satisfy the Word Minimality in O'odham. The statement of Word Minimality is repeated in (60).

(60) Word Minimality

A word must have at least two moras.

Thus, truncation of closed monosyllables with short vowels supports the importance of moras with respect to Word Minimality in O'odham.

2.4.2 Summary

The existence of moras in O'odham phonology is motivated by the lexical distinction of vowel lengths, reduplication, Word Minimality and truncation. The mora is an important element for O'odham phonology. I have provided evidence to show that Word Minimality in the form of a constraint that states that a word must be at least bimoraic, is active in O'odham phonology. A moraic account also explains the lexical distinction between the minimal words differing only with respect to vowel length. Also, reduplication and truncation exemplify mora and word minimality. These points are taken into account in OT analysis that follows.

2.5. Optimality Theoretic Analyses

I have described O'odham syllable structure and mora sensitivity in O'odham in the above sections. In this section, I show analyses of O'odham syllable structure assuming mora theory in the framework of Optimality Theory.

2.5.1 Constraints for O'odham Syllables

As shown in the preceding sections, Tohono O'odham syllable structure is restricted. An onset must be present, and is always filled with a single consonant. A word must be minimally bimoraic. To satisfy minimality, monosyllabic content words must have a coda when they have a short vowel. Most syllables need not have a coda when there is a long vowel because a long vowel is already bimoraic. Generally, codas are optional. Up to three consonants are allowed to share the same coda position. There is a restriction in the arrangement of the consonants in the complex coda: their sonority has to be either falling or flat obstruent. These characteristics of O'odham syllable structure are reviewed in (61).

(61) O'odham Syllable Generalizations

a. A word must have at least two moras.

b. A syllable must have an onset.

c. A syllable can have zero to three coda consonants.

d. A coda cluster's sonority is falling or flat (obstruent).

e. Long vowels are bimoraic.

f. A coda in monosyllable with a short vowel is moraic.

With these properties in mind, the constraints on O'odham syllable structure are presented and explained in the following sections. Definitions are given alongside the analysis.

(62) Constraints for O'odham Syllables

MORAINDISPENSABLITY (MI)

MINIMUMWORD (MINWD)

ONSET (ONS)

*COMPLEXONSET (*COMPONS)

FAITH(F)

The use of these constraints is shown in the following sections.

2.5.1.1 MORAINDISPENSABILITY

Vowels are expected to be moraic. A predictable factor like this must be phonologically accounted for. Here, I first introduce a constraint called MoraIndispensability, abbreviated as MI. It states that a vowel must have mora. The definition is given in (63).

(63) MORAINDISPENSABILITY (MI):

A vowel must have at least one mora.

The example evaluation with this constraint is shown in the tableau below.

(64) Example Evaluation with MI

		MI
a.	V	*!
√ b.	Vμ	
√ c.	Vμμ	

This indicates that as long as the vowel carries at least one mora, the candidate satisfies the constraint regardless of number of mora. Further discussion regarding this MI is presented in Chapter 3. This constraint is, however, assumed in this chapter and all the candidates represented are moraic.

2.5.1.2 MINIMUMWORD: Bimoraic Minimum

A minimal word is the smallest string of sounds that can be a content word. A content word is a major class word (i.e. Noun, Verb, Adjective, Adverb). To identify a minimal word in a language, we must look at monosyllables that are content words, because monosyllables are already the smallest unit within an infinite number of existing words. Also, since a syllable is minimally monomoraic, a polysyllabic word automatically contains more than one mora. Thus it is reasonable to look at only monosyllable words here.

A minimal word in Tohono O'odham is bimoraic (Fitzgerald 1997). This is shown by existing words in Tohono O'odham. The example words in (65) are all monosyllabic.

(65) Word Minimality

a.	kaa	'hearing'	* ka
b.	ʔoo	'back'	* ʔo
c.	kui	'tree'	* ku
d.	ʔaǰ	'narrow'	* ʔa
e.	čuk	'black'	* ču

As shown in (65), the words must either have a long vowel or a coda consonant to be a content word having at least two moras. All content words in O'odham must satisfy the MINWD constraint given in (66).

(66) MINIMUMWORD (MINWD):

A content word must contain at least two moras.

The tableau in (67) shows the evaluation of an O'odham content word *kii* 'house' with the MINWD constraint. Candidate (a) satisfies the constraint because it contains two moras. On the other hand, candidate (b) is rejected because it does not have enough mora. The correct candidate (a) is chosen.

(67) Evaluation of *kii* 'house'

	/ki/	MinWd
☞ a.	ki μμ	
b.	ki μ	*!

A polysyllable such as *tako* 'yesterday' has at least two moras. The first syllable *ta* must have at least one mora, and the second syllable *ko* must have at least one mora, totaling at least two moras. Therefore, the word *tako* satisfies the MINWD constraint. The evaluation of *tako* is shown in (68). The word contains two moras. Therefore, it satisfies the MINWD constraint.

(68) Evaluation of *tako* 'yesterday'[1]

	/tako/	MINWD
☞ a.	tako μμ	

All legal words satisfy the MINWD constraint because they possess more than one mora without fail. That is, this constraint is never violated. In order for it to be not violated, the constraint must be ranked very high. A constraint that is never violated is called an inviolable constraint. Hence, MINWD is inviolable in Tohono O'odham.

2.5.1.3 ONSET(ONS)

The ONS constraint is one of the most orthodox constraints in the history of OT (McCarth and Prince 1993, Prince and Smolensky 1993). O'odham also requires this constraint to be higher ranked. As shown in the data of (69), O'odham words always begin with consonants. No such word without an onset appears.

[1] There is a violation of Faith in the tableau. I will discuss it in the later sections.

(69) O'odham Onset

a.	mɨḍ	'running'	* ɨḍ
b.	ʔaʔan	'feather'	* aʔan
c.	ʔoo	'back'	* oo
d.	kaačim	'above'	* aačim
e.	ʔuwi̥	'woman'	* uwi̥

The constraint is defined again in (70).

(71) ONS:

A syllable must have an onset.

The evaluation with respect to ONS is shown in the tableau (72). Both candidates (a) and (b) satisfy MINWD, but the evaluation is deleted by ONS. Candidate (a) satisfies ONS by having a glottal stop [ʔ] consonant for its onset. Candidate (b), on the other hand, violates ONS for not having an onset, and is ruled out. Candidate (c) and (d) violate MINWD, additionally, candidate (d) violates ONS.

(72) Evaluation of *ʔoo* 'back'

	/ʔoo/	MINWD	ONS
☞ a.	ʔoo $\mu\mu$		
b.	oo $\mu\mu$		*!
c.	ʔo μ	*!	
d.	o μ	*!	*

Like the MINWD constraint, no O'odham content word violates this Onset constraint, therefore ONS is an undominated or inviolable constraint in Tohono O'odham. The ranking between MINWD and ONS is not strictly determined since neither is violated by the correct output.

2.5.1.4 *COMPLEXONSET

Although an O'odham word must have an onset, the onset is consistently filled by only one consonant,[1] as shown in the data in (73).

[1] With some exceptions, such as *tloogi* 'truck', etc. Only handful of words appear to have complex onset and they are always borrowed words from a language in which the original has such a complex onset. Also, when a possessive prefix is attached to a noun, the noun may appear to have a complex onset. For example, ñ-kii 'my house' or t-kii 'your house' have single consonants for their prefixes, as well as a sequence consisting of a single consonant prefix and single consonant onset that could form a complex onset by resyllabification. However, these tend to be pronounced with an epenthetic vowel schwa [ə], such as *ñə-kii* and *tə-kii*.

(73) O'odham Onset

a.	kii	'house'	* pkii
b.	ban	'coyote'	* kban
c.	čučul	'chiken'	* pčučul
d.	ṣoak	'crying'	* kṣoak

This characteristics define by the *COMPLEXONSET constraint, the definition of which is presented in (74):

(74) *COMPONS:

An onset must not have more than one consonant.

The tableau (75) below shows the evaluation of onset complexity. Both candidates satisfy MINWD and Onset because they contain two moras and begin with onset. However, candidate (b) violates *COMPONS for having more than one consonant in onset position, and therefore is ruled out. Candidate (a) satisfies this constraint because its onset is filled with only one consonant, and this is selected as an optimal candidate.

(75) Evaluation of *kii* 'house'

	/kii/	MINWD	ONS	*COMPONS
☞ a.	kii $\mu\mu$			
b.	pkii $\mu\mu$			*!

Again, *COMPONS is also an inviolable constraint as are MINWD and ONS. The ranking of these three constraints is equal among each other. All are undominated and inviolable.

2.5.1.5 FAITH(F)

The tableau above is easily evaluated using correspondence constraints. Others are important in the case that the input is illegal in form. FAITH(F) is used in this section in order to show the importance of the correspondence between features of input and output. The constraint is introduced in Prince and Smolensky (1993). Faithfulness is introduced as a combination of FILL and PARSE. McCarthy (1995), used it to account for feature phonology introducing MAP and DEP (c.f. McCarthy and Prince 1995). I adopt these constraints. Since there is no need to separate them regarding the corresponding direction, I keep them as one, calling it FAITH(F). The definition is given in (76):

(76) FAITH(F):

The features of input and output must be identical.

In other words, candidates are not allowed to have additional or lacking features. The evaluation with this constraint is illustrated in (77). Candidate (a) is the winner for not violating any constraint. Candidate (b) is thrown away because it violates MINWD. ONS rules out candidate (c) for lacking an onset. Candidate (d) has a complex onset, and therefore fails in validity. All failing candidates violate FAITH(F).

(77) Evaluation of *kii* 'house'

	/kii/	MINWD	ONS	*COMPONS	FAITH(F)
☞ a.	kii μμ				
b.	ki μ	*!			*
c.	ii μμ		*!		*
d.	pkii μμ			*!	*

This tableau does not show the necessity of FAITH(F), because all incorrect candidates violate other constraints. FAITH(F) is, however, an important constraint in Tohono O'odham. Its necessity, as well as all other constraints given above, is discussed in the following sections.

2.5.2 Necessity of Prosodic Constraints

In this section, the necessity of the prosodic constraints, MINWD, ONS and *COMPONS, is exemplified. Some might notice that if we have FAITH(F), then we do not need to have other constraints at all since all, failing candidates violate the faithfulness constraint as shown in (78).

(78) Evaluation of *kii* 'house'

	/kii/	FAITH(F)	MINWD	ONS	*COMPONS
☞ a.	kii μμ				
b.	ki μ	*!	*		
c.	ii μμ	*!		*	
d.	pkii μμ	*!			*

This tableau selects the correct output because the input is already in the correct form. Other candidates violate FAITH(F), so they are all ruled out. According to the principle of the Richness of the Base (McCarthy and Prince 1993, Prince and Smolensky 1993), however, any combination of sound segments can comprise input, and the constraint hierarchy still has to select the optimal output. That is, if the tableau has an incorrect form in input, a wrong candidate will be selected due to the nature of the FAITH(F) constraint when we do not have prosodic constraints such as MINWD, ONS and *COMPONS. The next tableau shows that the exclusive use of FAITH(F) derives the wrong evaluation when we use an incorrect form in input as shown in (79).

2.5.2.1 MINWD Necessity

First, the tableau (79) shows that MINWD is necessary. The wrong candidate is selected without MINWD. Because the input is monomoraic, nothing rules out the monomoraic candidate (b), /ki/.

(79) Evaluation of *kii* 'house', input /ki/, ill-formed

	/ki/	ONS	*COMPONS	FAITH(F)
a.	kii $\mu\mu$			*!
☞ b.	ki μ			
c.	ii $\mu\mu$	*!		*
d.	pkii $\mu\mu$		*!	*

The MINWD constraint is necessary in order for the correct candidate to be identified, as shown in (80). Although the monomoraic candidate (b) satisfies FAITH(F), it is ruled out by MINWD.

(80) Evaluation of *kii* 'house', input /ki/, ill-formed

	/kii/	MINWD	ONS	*COMPONS	FAITH(F)
☞ a.	kii $\mu\mu$				*
b.	ki μ	*!			
c.	ii $\mu\mu$		*!		*
d.	pkii $\mu\mu$			*!	*

Also, the ranking of MINWD must be higher than that of FAITH(F). Otherwise, the wrong candidate will emerge, as illustrated in (81).

(81) Evaluation of *kii* 'house', input /ki/, ill-formed

	/ki/	ONS	*COMPONS	FAITH(F)	MINWD
a.	kii μμ			*!	
☞ b.	ki μ				*
c.	ii μμ	*!		*	
d.	pkii μμ		*!	*	

When MINWD is ranked lower than FAITH(F), the incorrect candidate (b) is chosen. Therefore, MINWD must be ranked higher than FAITH(F), as outlined in (82).

(82) Constraint Ranking

MINWD >> FAITH(F)

2.5.2.2 ONS Necessity

The next tableau (83) demonstrates the necessity of ONS. The input is /ii/. Without ONS, the incorrect candidate (c) is chosen because it does not violate any constraints while remaining candidates violate at least one of the other constraints.

(83) Evaluation of *kii* 'house', input /ii/, ill-formed

	/ii/	MINWD	*COMPONS	FAITH(F)
a.	kii $\mu\mu$			*!
b.	ki μ	*!		*
☞ c.	ii $\mu\mu$			
d.	pkii $\mu\mu$		*!	*

As shown in (84), with ONS, the correct candidate is the winner. The ONS constraint ruled out candidate (c) for not having an onset.

(84) Evaluation of *kii* 'house', input /ii/, ill-formed

	/ii/	MINWD	ONS	*COMPONS	FAITH(F)
☞ a.	kii $\mu\mu$				*
b.	ki μ	*!			*
c.	ii $\mu\mu$		*!		
d.	pkii $\mu\mu$			*!	*

This ONS constraint must be ranked higher than FAITH(F). When ONS is ranked lower than FAITH(F), the wrong output is selected as shown in (85).

(85) Evaluation of *kii* 'house', input /ii/, ill-formed

	/ii/	MINWD	*COMPONS	FAITH(F)	ONS
a.	kii μμ			*!	
b.	ki μ	*!		*	
☞ c.	ii μμ				*
d.	pkii μμ		*!	*	

Thus, ONS must be ranked higher than FAITH(F) as well as MINWD. The ranking is shown in (86). MINWD and ONS are ranked equally, which means that their raking does not matter.

(86) Constraint Ranking

MINWD, ONS >> FAITH(F)

2.5.2.3 *COMPONS Necessity

In this section, the necessity of *COMPONS is shown. The tableau (87) shows the evaluation of kii 'house' with the ill-formed input /pkii/. Candidate (d), which is an incorrect form, is chosen without *COMPONS because it does not violate any constraint in the tableau.

(87) Evaluation of kii 'house', input /pkii/, ill-formed

	/pkii/	MINWD	ONS	FAITH(F)
a.	kii $\mu\mu$			*
b.	ki μ	*!		**
c.	ii $\mu\mu$		*!	*
☞ d.	pkii $\mu\mu$			

The next tableau (88) shows the evaluation with *COMPONS. Because *COMPONS rules out candidate (d), which was the incorrectly chosen candidate in (87), the correct candidate (a) is the winner.

(88) Evaluation of kii 'house', input /pkii/, ill-formed

	/pkii/	MINWD	ONS	*COMPONS	FAITH(F)
☞ a.	kii $\mu\mu$				*
b.	ki μ	*!			**
c.	ii $\mu\mu$		*!		*
d.	pkii $\mu\mu$			*!	

The ranking of the *COMPONS must be higher than FAITH(F). If it is ranked lower than FAITH(F), the incorrect candidate is selected, as shown in (89).

(89) Evaluation of kii 'house', input /pkii/, ill-formed

	/pkii/	MINWD	ONS	FAITH(F)	*COMPONS
a.	kii $\mu\mu$			*!	
b.	ki μ	*!		**	
c.	ii $\mu\mu$		*!	*	
☞ d.	pkii $\mu\mu$				*!

Therefore, *COMPONS must be ranked higher than FAITH(F). The constraint ranking is shown in (90). MINWD, ONS and *COMPONS outrank FAITH(F).

(90) Constraint Ranking

MINWD, ONS, *COMPONS >> FAITH(F)

In the above analysis, I have shown the necessity of prosodic constraints. In other words, the tableau above selects the correct output even with an ill-formed input.

2.5.2.4 Necessity of FAITH(F)

FAITH(F) is also necessary when an ill-featured candidate is in the candidate set. Consider the following tableau (91). Candidate (a) is the correct output. Candidates (b), (c) and (d) are ruled out for violating one of the prosodic constraints. Candidate (e) is prosodically well-formed syllable, [pii]. It satisfies all prosodic constraints because it is bimoraic, has onset, and only one consonant is in the onset. Thus this candidate is also selected when FAITH(F) is not factored in.

(91) Evaluation of *kii* 'house'

	/kii/	MINWD	ONS	*COMPONS
☞ a.	kii μμ			
b.	ki μ	*!		
c.	ii μμ		*!	
d.	pkii μμ			*!
💣 e.	pii μμ			

This candidate, however, violates FAITH(F) for having the wrong feature [p] in the onset instead of the correct feature [k]. When we have FAITH(F), candidate (e) fails for violating FAITH(F), and only the correct candidate (a) is selected as shown in (92).

(92) Evaluation of *kii* 'house'

	/kii/	MINWD	ONS	*COMPONS	FAITH(F)
☞ a.	kii μμ				
b.	ki μ	*!			*
c.	ii μμ		*!		*
d.	pkii μμ			*!	*
e.	pii μμ				*!

I have shown the necessity of both prosodic constraints, MINWD, ONS and *COMPONS and correspondence constraint FAITH(F). I used the open monosyllable, CVV[1] for the example evaluation above. An evaluation of closed syllables is shown in the next section as I discuss the relationship between Input and Output.

2.5.3 Closed Syllables

In this section, I show several evaluations using closed syllables. The syllable type used in this section and the words used are given in (93).

(93) Syllable Types[2]

	Syllables		Example Word	
a.	CVC	Closed, Short vowel	him	'walking'
b.	CVVC	Closed, Long vowel	baab	'grandmother'

Tableau (94) shows the evaluation of the verb *him* 'walking, singular, imperfective.' Candidate (a) violates none of the constraints. Candidate (b) has only one mora, and is therefore ruled out by MINWD. Candidate (c) lacks an onset, violating ONS. Candidate (d) has the initial consonant cluster [ph], which is ruled out by *COMPONS.

---

[1] An open syllable with short vowel is not shown because it does not appear as a content word in the language.

[2] The representative syllable types are all monosyllables.

(94) Evaluation of *him* 'walking'

	/him/	MINWD	ONS	*COMPONS	FAITH(F)
☞ a.	him μμ				
b.	hi μ	*!			*
c.	im μμ		*!		*
d.	phim μμ			*!	*

Tableau (95) shows the evaluation of *baab* 'grandmother'. The input is well-formed. Candidate (a) is the correct output. It does not violate any constraint. Other candidates violate at least one of the prosodic constraints, as well as FAITH(F), at least once. Candidate (b) lacks at least one additional mora in order to satisfy MINWD. Candidate (c) violates ONS for not having onset, and candidate (d) has too many consonants in an onset position. Hence candidate (a) is the correct output.

(95) Evaluation of *baab* 'grandmother'

	/baab/	MINWD	ONS	*COMPONS	FAITH(F)
☞ a.	baab μμ				
b.	ba μ	*!			**
c.	aab μμ		*!		*
d.	kbaab μμ			*!	*

2.5.4 Input and Output

In this section, I show evaluations with well-formed input and ill-formed input. According to *richness of the base* (McCarthy and Prince 1993), any form can be input and yet the optimal candidate will be the form that is acceptable in the language. That is, the constraints and the ranking provided above will also work for ill-formed input. Evaluation with ill-formed input is shown in the following tableaux. The ill-formed input is listed in (96).

(96) Ill-formed Inputs

a. hi

b. im

c. phim

Tableau (97) has the ill-formed input /hi/. Candidate (a), which satisfies all constraints, is the correct output. Candidate (b) is excluded for violating MINWD by not having at least two moras. Candidate (c) is ruled out because there is no onset, and candidate (d) also fails because it violates *COMPONS. The last candidate violates FAITH(F), and is excluded. This form would be correct and acceptable output if a Tohono O'odham word were generated based on the ill-formed input /hi/.[1]

---

[1] [hii] is actually an existing word in O'odham but it is a perfect form of [him] that undergoes truncation. The formation of truncated words in terms of OT is discussed in Fitzgerald and Fountain (1997).

(97) Evaluation of Ill-Formed Input /hi/

	/hi/	MINWD	ONS	*COMPONS	FAITH(F)
☞a.	hii μμ				
b.	hi μ	*!			
c.	im μμ		*!		**
d.	phim μμ			*!	**
e.	him μμ				*

In the above tableaux, mora faithfulness is ignored. The moraic structure is analyzed in Chapter 3.

Tableau (98) has the ill-formed input /im/, which lacks onset. Candidate (a) is the selected output. In other words, it is the acceptable form that is generated based on the ill-formed input /im/. Candidate (b) violates FAITH(F) twice for having [h] and lacking [m]. Candidate (c) is excluded because it violates MINWD. Candidate (d), which is identical to the input, does not violate FAITH(F). However, it does violate the ONS constraint which is ranked higher than FAITH(F), and thus it is ruled out. Candidate (e) violates *COMPONS by having two consonants in one onset position.

(98) Evaluation of ill-formed input /im/.

	/im/	MINWD	ONS	*COMPONS	FAITH(F)
☞ a.	him μμ				*
b.	hii μμ				*!*
c.	hi μ	*!			*
d.	im μμ		*!		
e.	phim μμ			*!	*

The winning candidate (a) is actually not only optimal output, since the crucial point that makes input ill-formed is lack of onset. If output is anything having the same form as the input, with a single onset within an O'odham phoneme appearing, onset will be chosen. For example, even [kim], [him], and [sim] would also be acceptable output in O'odham.

Tableau (99) shows the evaluation with the ill-formed input /phim/. The input has complex onset, which is illegal in O'odham. Candidate (a) is the optimal input; this is acceptable input generated by ill-formed input. Candidate (b) is excluded because it violates MINWD. Candidate (c) is also ruled out because it violates ONS for lacking onset. Candidate (d), which is identical to the input, does not violate FAITH(F), but it is ruled out since it violates *COMPONS, which is ranked higher than FAITH(F).

(99) Evaluation, ill-formed input /phim/.

	/phim/	MINWD	ONS	*COMPONS	FAITH(F)
☞ a.	him $\mu\mu$				*
b.	hi μ	*!			**
c.	im $\mu\mu$		*!		**
d.	phim $\mu\mu$			*!	

Evaluation of a closed monosyllable with ill-formed input has been shown. Constraints and ranking select acceptable output in Tohono O'odham even when ill-formed input is used. The constraints and the ranking are again shown in (100).

(100) Ranking

MINWD, ONS, *COMPONS >> FAITH(F)

2.5.5 Coda Clusters

In this section, I show analysis of coda consonant clusters. O'odham codas can contain multiple consonants, and the number is restricted to one, two or three. The maximum number of consonants in a coda position can be determined by an OT constraint. Before we go into depth, there is one constraint I must mention: *COMPCODA. We have already seen *COMPONS in preceding sections, but *COMPCODA has not been mentioned so far. This is the counterpart of *COMPONS within the *Complex family. Just as *COMPONS restricts onset to be single, *COMPCODA constrains a coda to be a single consonant. The definition is as given in (101).

(101) *COMPCODA:

A coda must not have more than one consonant.

This *COMPCODA constraint must be ranked lower than FAITH(F) in O'odham. Tableau (102) shows the incorrect evaluation due to the faulty ranking of *COMPCODA. In tableau (102), *COMPCODA is ranked higher than FAITH(F). The correct candidate is (a), but it does not win and the wrong candidate (b) is selected because candidate (a) violates *COMPCODA for having a complex coda, while candidate (b) does not violate this constraint. Although candidate (b) violates FAITH(F), which is not violated by candidate (a), candidate (b) still prevails because of the ranking that *COMPCODA dominates FAITH(F).

(102) Evaluation of *ṣopolk* 'short'

	/ṣopolk/	MINWD	ONS	*COMPONS	*COMPCODA	FAITH(F)
a.	ṣopolk μ μ				*!	
💣 b.	ṣopol μ μ					*

In order to avoid such misanalysis, the ranking must be differentiated as shown in (103):

(103) Rank of FAITH(F)

FAITH(F) >> *COMPCODA

Tableau (104) shows the correct evaluation with the correct ranking. Now the rank of *COMPCODA is lower than FAITH(F). Candidate (b) is ruled out by FAITH(F). Candidate (a) does not violate FAITH(F), and is selected. The violation of *COMPCODA by candidate (a) is not crucial anymore because the constraint is ranked lower than FAITH(F).

(104) Evaluation of *ṣopolk* 'short'

	/ṣopolk/	MINWD	ONS	*COMPONS	FAITH(F)	*COMPCODA
☞ a.	ṣopolk μ μ					*
b.	ṣopol μ μ				*!	

The ranking so far is shown in (105).

(105) Consonant and Ranking

MINWD, ONS, *COMPONS >> FAITH(F) >> *COMPCODA

2.5.5.1 Restriction of Cluster Size

As I mentioned before, O'odham coda clusters are allowed to have up to three consonants. The restriction may not necessarily be made, but a discussion regarding cluster size is given in the following paragraphs.

Pierrehumbert (1994) claims that what is called "ill-formed" grammar can be reduced to "statistically impossible." She looks at tri-consonantal clusters in English and suggests that the fact certain clusters do not appear is explained by frequency. She looks only at word-medial consonant clusters, whereas my examination deals with only word-final positions. Because the type of clusters looked at in her study is not relevant, I merely describe the occurrence of consonant clusters in coda position.

I will call words ending in at least one consonant Group A, words ending in at least two consonants Group B, words ending in at least three consonants or Group C, and words ending in four consonants Group D. There are 7739 words out of more than 11,000 entries scanned in Group A, and 873 in Group B. That is, 11.2% of Group A words end in two consonants or more. Out of the 873 words in Group B, 103 words fall into Group C, in which words end in at least three consonants. 11.7% of Group B has three consonantal endings. Group D contains no words.

If we believe that the occurrence of four consonant clusters is proportional to the percentage of group C, we would have to see at least 11 words with four coda consonant clusters in Group D. Again, no word that ends in four consonants exists in the corpus.

This demonstrates that, the restriction of the number of coda consonants is categorical; not probabilistic.

(106) **Cluster Sizes**

Group A	XCVC+	7739	
Group B	XCVCC+	873	11.2% of A
Group C	XCVCCC+	103	11.7% of B
Group D	XCVCCCC+	0	0% of C

This fact in the non-proportional numbers might support the claim that Tohono O'odham has a restriction in number of coda consonant clusters, such that the O'odham syllable cannot have more than four consonants in one coda position. Such a constraint might be descriptived in (107).

(107) ***CODACONDITION(C^{4+}):**

Four or more consonants cannot be in one coda position.

This constraint attempts to explain the restriction in number of consonant clusters. In tableau (108) below, the evaluation with the constraint is shown. Candidate (b) is the correct candidate. Candidate (a) is incorrect because it violates FAITH(F). Candidate (c) is also incorrect. It violates both CODACOND(*C^{4+}) and FAITH(F).

(108) Evaluation of *mamtk* 'palm of the hand'

	/mamtk/	CODACOND(*C^{4})	FAITH(F)	*COMPCODA
a.	mamt		*!	*
☞ b.	mamtk			*
c.	mamtkt	*!	*	*

Note that the constraint ranking. In (108), CODACOND(*C^{4+}) dominates FAITH(F).

(109) Constraint Ranking

CODACOND(*C^{4}) >> FAITH(F) >> *COMPCODA

In tableau (108) above, since the two incorrect candidates (a) and (c) violate FAITH(F) and the correct candidate (b) does not, the importance of CODACOND(C^{4+}) may not be clearly shown.

Tableau (110) below shows the importance of the ranking given in (109). The ill-formed input has four coda consonants [-mtkt]. If CODACOND(C^{4+}) is ranked lower than FAITH(F), the incorrect candidate (c) will be selected because it does not violate FAITH(F). In order for the incorrect candidate (c) to be ruled out, FAITH(F) must dominate CODACOND(C^{4+}).

(110) Evaluation of *mamtk* 'palm of the hand', ill-formed input

	mamtkt	CODACOND(*C⁴)	FAITH(F)	*COMPCODA
a.	mamt		*!*	*
b.	mamtk		*	*
c.	mamtkt	*!		*
d.	mamtktk	*!	*	*

2.5.5.2 Sonority in Clusters

Although it is difficult to determine a limit in the number of allowable consonant clusters, it is possible to examine and analyze sonority restriction in such clusters. Consider the following tableau (111), an analysis of *ṣopolk* 'short' with well-formed input. The correct output is selected. Candidate (b) violates FAITH(F), and so it is ruled out.

(111) Evaluation of *ṣopolk* 'short'

	/ṣopolk/	MINWD	ONS	*COMPONS	FAITH(F)	*COMPCODA
☞ a.	ṣopolk μ μ					*
b.	ṣopokl μ μ				*!	*

On the other hand, when input is ill-formed, having a rising sonority in the coda, an incorrect evaluation is seen as in (112). The correct candidate fails for violating FAITH(F), and the incorrect candidate (b) is chosen.

(112) Evaluation of *ṣopolk* 'short', input /ṣopokl/, ill-formed

	/ṣopokl/	MINWD	ONS	*COMPONS	FAITH(F)	*COMPCODA
a.	ṣopolk μ μ				*!	*
☞ b.	ṣopokl μ μ					*

In tableau (112) above, the incorrectly winning candidate must not be selected because it contains an ill-formed arrangement of consonant clusters.

In earlier sections, I mentioned that sonority sequence matters in the coda consonant clusters. As I described earlier, Tohono O'odham has a two-level sonority scale consisting of sonorant and obstruent, and the correct and incorrect sonority sequences are shown below. S stands for sonorant and O for obstruent. (113a) and (113)b are correct sequences and (113c) and (113d) are incorrect.

(113) Sonority in Coda

a. SO √

b. OO √

c. SS *

d. OS *

The two sequences of sonorant followed by obstruent, and obstruent followed by another obstruent are both allowed. Conversely, the sequences of sonorant followed by another sonorant and obstruent followed by a sonorant are illegal. This probability is generalized into one form as shown in (114):

(114) *X[S]

And I use this generalization for the new constraints regarding sonority sequence in O'odham Coda, as demonstrated in (115).

(115) Coda(*X[S]):
In the coda position, the sequence of a consonant followed by a sonorant is prohibited.

The evaluation with this constraint is shown in (116). Candidate (a) satisfies the new constraint because the coda's sonority sequence is a sonorant followed by an obstruent. Candidate (b) violates the constraint for its coda's sonority sequence; an obstruent followed by a sonorant. Hence candidate (a) wins.

(116) Evaluation of *ṣopolk* 'short', input /ṣopokl/, ill-formed

	/ṣopokl/	MINWD	ONS	*COMPONS	CODA(*X[S])	FAITH(F)	*COMPCODA
☞ a.	ṣopolk μ μ					**	*
b.	ṣopokl μ μ				*!		*

The CODA(*X[S]) constraint must be ranked higher than FAITH(F) as shown in tableau (116). When it is ranked lower than FAITH(F), an incorrect evaluation is derived as shown in (117). When FAITH(F) dominates CODA(*X[S]), candidate (a) is ruled out because it violates FAITH(F), and the incorrect output (b) is selected.

(117) Evaluation of *ṣopolk* 'short', input /ṣopokl/, ill-formed

	/ṣopokl/	MINWD	ONS	*COMPONS	FAITH(F)	CODA(*X[S])	*COMPCODA
a.	ṣopolk μ μ				*!*		*
☞ b.	ṣopokl μ μ					*	*

Therefore, the ranking of the constraints with CODA(*X[S]) is as shown below in (118).

(118) Constraint and Ranking

MINWD, ONS, *COMPONS, CODA(*X[S]) >> FAITH(F) >> *COMPCODA

2.5.5.3 Triple Consonant Clusters

In this section, an analysis of triple consonant coda is presented. The possible sonority sequences are listed below. Illegal sequences in O'odham are marked with an asterisk (*).

(119) Possible Sonority Sequence in Triple Consonant Coda

a.	OOO	√	e.	SSS	*
b.	SOO	√	f.	OOS	*
c.	SSO	*	g.	OSS	*
d.	OSO	*	h.	SOS	*

Only the sequences OOO and SOO are legal augmentation in O'odham coda. The sonority sequence of a triple consonant cluster is either a sonorant followed by an obstruent which is followed by another obstruent, or an obstruent followed by another obstruent which is also followed by another obstruent. If we look at the illegal sequences, all consist of a consonant followed by a sonorant. As I described in an earlier section, this triple consonant sequence is also generalized with the same form that is used for double consonant clusters, as seen in (120)

(120) *X[S]

This suggests that we can use the same constraint introduced above to evaluate triple consonant clusters.

In tableau (121), the evaluation of a word with three consonants in the coda is shown. The tableau has an ill-formed input. Candidate (a) is the winner even though it violates FAITH(F). The FAITH (F) constraint is ranked below the CODA(*X[S]) constraint that is violated by the other two candidates. Candidate (b) is in violation for having the sonority sequence of [obstruent] followed by [sonorant], and candidate (c) violates the constraint for its sonority sequence of two sonorant consonants. Therefore, the correct candidate (a) is chosen.

(121) Evaluation of ill-formed input /gɨpwṣ/

	/gɨpwṣ/ (OSO)	MINWD	ONS	*COMPONS	CODA(*X[S])	FAITH(F)	*COMPCODA
☞ a.	gɨwṣp (SOO)					**	*
b.	gɨpwṣ (OSO)				*OS		
c.	gɨwwp (SSO)				*SS	**	*

As shown above, the sonority sequencing constraint CODA(*X[S]) takes care of both double and triple consonant clusters in O'odham coda.

2.5.5.4 Word Medial Clusters

Evaluation of word medial clusters is shown in this section. Finding a syllable boundary is the goal. Tableau (122) shows such an evaluation with these two constraints.

Candidate (a) is the correctly syllabified output. Its second syllable has onset that is not complex. The sonority sequence in the coda of the first syllable satisfies CODA(*X[S]). Candidate (b) fails because the second syllable has no onset. Candidate (c) is ruled out because there is more than one consonant in the onset position of the second syllable. Candidate (d) is excluded because sonority sequence in the coda of the first syllable violates CODA(*X[S]). Finally, candidate (e) is ruled out because it violates Faith(F) for having the [+nasal] feature in [m] that is not seen in the input.

(122) Evaluation of giwpkdag **'somebody's power, distributive'**

	giwpkdag	MW	ONS	*COMPONS	CODA(*X[S])	FAITH(F)	*COMPCODA
☞ a.	giwpk.dag (SOO)						*
b.	giwpkd.ag (SOO)		*!				
c.	giwp.kdag (SO)			*!			
d.	gipwk.dag (OSO)				*(OS)!	*	
e.	gimpk.dag (SOO)					*!	

Thus the constraints and the ranking given above are still valid. For the evaluation of word medial clusters, the crucial point is to find the correct syllable boundaries. Correct syllable boundaries are found via undominated constraints, ONS and *COMPONS. All other remaining factors are evaluated by the next higher ranked constraints such as CODA(*X[S]) and FAITH(F).

2.6 Conclusion

In this chapter, I have described and analyzed the basic syllable structure of Tohono O'odham. A syllable must have an onset and the onset consonant must be simple. A syllable may have one, two or three coda consonants. Codas are not necessarily moraic, but they are realized as moraic when appearing in a monosyllable word with a short vowel. Coda consonant clusters are restricted in sonority. They are required to consist of an obstruent or sonorant followed by one or more obstruent consonants. The consonant closest to the vowel can be either sonorant or obstruent but others must be obstruent, avoiding the sequence of a consonant preceding a sonorant.

These generalizations are captured in Optimality Theory. The constraints and the ranking represent the occurrence of O'odham words. ONS is higher ranked because O'odham syllables must have syllable, but *COMPONS also must be ranked high because the onset is always a single consonant. MINIMUMWORD is undominated, too, for O'odham words must be at least bimoraic. O'odham syllables can have coda which allows consonant clusters. So NOCODA and *COMPCODA are lower ranked constraints. However, the sonority of the O'odham coda clusters does not contain the sequence [[obstruent] [sonorant]] and [[sonorant] [sonorant]], and therefore, CODA(*X[S])is ranked relatively higher. Also, the number of coda consonants is restricted to three or fewer. This is analyzed by CODACOND(*C^{4+}). The ranking is:

(123) Ranking

{ WDMIN
ONS
*COMPONS
CODACOND(*C^{4+})
CODA(*X[S]) } FAITH(F) >>*COMPCODA

This is a basic view of Tohono O'odham prosody. Based on the analysis given above, I explain Tohono O'odham words with diphthongs in the next chapter. Some of these undominated constraints will not appear in tableaux, because these constraints are assumed and candidates that violate those constraints are omitted.

CHAPTER 3: O'ODHAM DIPHTHONGS AND SYLLABLE WEIGHT

3.1 Introduction

In this chapter, analyses of the moraic structure of Tohono O'odham regarding syllables with diphthongs are provided. Tohono O'odham possesses additional classifications in diphthongs aside from falling vs. rising. In my analysis, diphthongs in Tohono O'odham are divided into two groups based on their weight: light and heavy. The property of heavy diphthongs is analogous to that of long vowels, and light diphthongs behave more like short vowels. This classification is based on properties of stress assignment and internal syllable structures. Also, I show the moraic structure with regards to weight which is an important factor in Tohono O'odham. Word Minimality strictly governs the phonology in O'odham, resulting in a moraic shift in light diphthongs found in codaless monosyllabic words. My analysis explores exceptionally stressed segments. This exceptional group supports my theory, while providing a detailed, careful analysis of the relationship between stress and weight in Tohono O'odham.

The outline of this chapter is as follows. First, general information about diphthongs is provided. Second, characteristics of O'odham diphthongs are described. Third, OT analyses of light and heavy diphthongs in Tohono O'odham are presented. The analyses are given by classes. Finally, I provide an OT analysis of diphthongs in words with exceptional stress assignment. As I mentioned in Chapter 1, the basic data are taken from a dictionary compiled by Mathiot (1973), with the dialect of Tohono O'odham collected mainly from Jewak, 'Covered Wells'.

3.1.1 Diphthongs

In this section, the basic concept of diphthong is presented. A vowel is classified as a *diphthong* when a change in its vowel quality within a single syllable is perceived. This change is represented with two symbols for vowels in sequence, indicating the change (Crystal 1980). For example, the O'odham word *hiawul* 'poison' contains a diphthong in the first syllable, and it is represented as [ia] to show the vowel has the quality of [i] and [a] in sequence. On the other hand, a vowel is classified as a *monophthong* when no such change is heard. Example representations in O'odham are [a] *tako* 'yesterday', [i] *him* 'walking' and [u] *cucul* 'chiken'.[1]

3.1.2 O'odham Diphthongs

In this section, a description of O'odham diphthongization is presented. Tohono O'odham has a relatively large number of diphthongs. Any combinations of the five basic vowels [i], [ɨ], [a], [o] and [u] appear except for the six combinations [uɨ], [oɨ], [aɨ], [ou], [uo] and [ao] (Saxton et. al. 1983), resulting in 14 existing diphthongs among 20 logically potential ones illustrated in (1). The sounds shown in the left-most column are the first element of the diphthongs and the sounds shown in the top row are the second elements in the diphthong. In the table below, [---] is marked when the combination creates a long vowel due to the sequence of two identical vowels. Such a combination will not be considered a diphthong here, for I define a diphthong as a vowel that can be heard with a perceptual change in its quality.

[1] A vowel is classified as a long vowel when it is heard without a change in its quality and the duration of the vowel is robustly longer than a regular or short vowel. A long vowel is represented with either double vowel such as [ii] or with a colon such as [i:].

(1) Tohono O'odham Diphthongs

		Second element				
		i	ɨ	u	o	a
First element	i	---	iɨ	iu	io	ia
	ɨ	ɨi	---	ɨu	ɨo	ɨa
	u	ui	**uɨ**	---	**uo**	ua
	o	oi	**oɨ**	**ou**	---	oa
	a	ai	**aɨ**	au	**ao**	---

As shown above, the six diphthongs that never appear in O'odham are indicated by shading. The others do appear in the language. These 14 diphthongs are seen in the following example words:

(2) O'odham Diphthongs

iɨ	unattested[2]	
iu	hiw**iu**m	'shave'
io	k**io**hod	'rainbow'
ia	b**ia**	'dishout'
ɨi	b**ɨi**	'accept'
ui	k**ui**	'mesquite tree'

[2] Although Saxton et al claim that all the vowel sequences except for the shaded ones in (1) occur, there is no example word that contains [iɨ] is listed in the entries. Also, no such sequence is found in Mathiot's dictionary. A sequence of [vowel]-[glottal]-[vowel] may be considered a diphthong depending on the literature (cf. Saxton 1963). However, I consider a sequence of two vowels with no glottal sound

oi	**hoin**	'greet'
ai	**baik**	'tail'
iu	**hium**	'to get cold'
io	**cioj**	'boy'
ia	**ñial**	'visit expecting a gift or a meal'
ua	**cua**	'grind'
oa	**koa**	'forehead'
au	**naupait**	'make wine'

3.1.3 Falling and Rising Diphthongs

Diphthongs are usually classified into two categories: *falling* and *rising*. This distinction is determined by prominence. Prominence is phonological or perceptual salience in a sequence of sounds. It is usually used to determine the stressed syllable in a word. Prominence can manifest itself as the *duration*, *amplitude* or *sound frequency* of a syllable, or as a combination of two or all of them. Prominence is also used to determine the type of diphthong. When the first element of the diphthong receives the prominence, it is a *falling* diphthong, and when the second element receives the prominence, it is a *rising* diphthong. The example in (3) below shows such a classification.

intervening t be a diphthongs. I did not treat the sequence of [vowel]-[glottal]-[vowel] as a diphthong in my analysis.

(3) Falling vs. Rising

Prominence is indicated by the stress mark [˙]

a. Falling diphthong

v̇v

b. Rising diphthong

vv̇

As I already mentioned, prominence is used in order to determine the diphthong type. Although prominence is generally the relative degree of duration, amplitude or frequency, the prominence for a diphthong seems to exist at the level of sonority (cf. Booij 1989). Sonority is the relative degree of loudness in a sound segment. Vowels are more sonorous than consonants, and there are varying levels of sonority among vowels. The lower the height of a vowel, the higher the sonority. Therefore, low vowels are the most sonorous vocalic segments and high vowels are the least. Sonority in vowels is shown in (4):

(4) Sonority in Vowels

More sonorous	↑	Low Vowel
	↕	Mid Vowel
Less sonorous	↓	High Vowel

In general, as shown below, when the first element of the diphthong is more sonorous than the other element, the diphthong is rising. On the other hand, when the first element of the diphthong is less sonorous than the other element, the diphthong is falling. A rising diphthong is illustrated with regards to the sonority in (5). The two vocalic elements in a diphthong are identified by V_1 and V_2 in sequence. In a rising diphthong, the sonority of V_1 is smaller than V_2. Thus, a rising diphthong is the sequence of a less sonorous vowel followed by a more sonorous vowel. The examples are [ia], [io], etc.

(5) **Rising in Terms of Sonority**

A diphthongs V_1V_2 is rising

When $V_1 < V_2$

e.g. [ia], [io]

Italian has rising diphthongs. The sounds [uɔ] as in *nuovo* 'new' [nuɔvo] and [iɛ] as in *piede* 'foot' [piɛde] are examples of rising diphthongs (Booij 1989). The first element is less sonorous than the second element.

The falling diphthong is illustrated next in (6). The sonority of V_1 is greater than V_2. A falling diphthong is the sequence of a more sonorous vowel followed by a less sonorous vowel. The examples are [ai], [oi], etc.

(6) **Falling in Terms of Sonority**

a diphthong V_1V_2 is falling

When $V_1 > V_2$

e.g. [ai], [oi]

English [ay] as in *typhoon* [tayfun] and [aw] as in *cow* [kaw] are falling diphthongs because their first elements are more prominent (Crystal 1980).

3.1.3.1 Falling and Rising Diphthongs in O'odham

O'odham seems to have both types of diphthongs. According to the sonority difference, rising and falling diphthongs in O'odham, are shown in (7):

(7) Raising vs. Falling Diphthongs

a. Rising: First element less sonorous

[io].[ia], [ɨo], [ɨa], [ua], [oa]

b. Falling: First element more sonorous

[oi], [ai], [au]

There are 6 rising diphthongs as shown in (7a) above. The first elements of these diphthongs are all high vowels, and therefore they are the least sonorous among the vowels. Also note that the second elements are more sonorous than the first elements, hence they are rising diphthongs. Likewise, there are three diphthongs found as shown in (7b). The second elements are high vowels and they are less sonorous than the first elements, creating the falling sonority. Thus they are falling diphthongs.

However, 5 other diphthongs that exist in O'odham do not fall into either category. They are shown in (8).

(8) Indifferent Diphthongs

Neither:

[iɨ], [iu], [ɨi], [ui], [ɨu]

These diphthongs consist of two vowels among [i], [ɨ] and [u]. Since the three vowels [i], [ɨ] and [u] have the same height, it is difficult to determine their diphthong type by sonority. As possible solutions to this, we can assume finer distinction in sonority among these high vowels. However, it does not seem convincing to make such a distinction with the sonority being so close among them.

Instead, we can assume that there is another category for these diphthongs in Tohono O'odham. Moreover, we can assume that this falling/rising classification is not important in O'odham phonology, leaving some other phonological property to be the key for classifying Tohono O'odham diphthongs. I claim that this "other phonological property" is quantity, which is discussed in the following sections.[3]

3.1.4 Weight of Diphthongs

In this section, the internal structure of a diphthong is outlined in order to provide background knowledge for my analysis. A single vowel is usually monomoraic unless it is a long vowel. A long vowel is bimoraic, and a diphthong is often considered heavy or bimoraic because it consists of two different vowels. As shown in (9), two elements in a diphthong are associated with two moras as in (9)a, and so is a long vowel as in (9)b.

(9) Bimoraic Vowels

a. Diphthong	b. Long vowel
V V	V
| |	/\
μ μ	μ μ

[3] Miyashita (2000a) claims that the high front vowel [i] appear to be a devoiced vowel more often than other vowels in Tohono O'odham.

It is, however, possible for one diphthong to be monomoraic. In this case, two elements of a diphthong must share one mora as shown in (10). Note that moraicity of monomoraic diphthong is analogous to a short vowel.

(10) Monomoraic Vowels

a. Diphthong

V V
\/
μ

b. Short vowel

V
|
μ

Both a diphthong and a short vowel are associated to a single mora.

Weight of diphthongs can differ cross-linguistically. It is common for a language to have only bimoraic diphthongs, yet monomoraic diphthongs are also found in other languages. For example, Fijian has light diphthongs (Hayes 1995). However, light diphthongs in other languages like Fijian tend to be the result of a phonological process. In Fijian, a bimoraic monosyllable word is shortened when a moraic suffix is attached. As in (11)a, *nré:* turns out to *nré-ta* with the vowel shortening. And this is applied to a diphthong as in (11)b.

(11) Fijian Vowel Shortening

a. Monophthong

nre: 'pull'		nre + ta		nre-ta 'pull-TRANS'
/\	→	/\ |	→	| |
μ μ		μ (μ) μ		μ μ

b. Diphthong

rai 'see'		rai + ða		rai-ða 'see it'
/\	→	/\ |	→	| |
μ μ		μ (μ) μ		μ μ

Thus, in Fijian, a light or monomoraic diphthong exists as a result of a phonological process called shortening.

In O'odham, however, some diphthongs are bimoraic and other diphthongs are monomoraic. The distribution of both bimoraic and monomoraic types is described in a later section.

3.1.5 Diphthong or Hiatus

Before we move on to deeper analysis, let us describe the true value of O'odham diphthongs. One may think that a diphthong is the result of hiatus. Hiatus is realized when we see a sequence consisting of a vowel-ending syllable followed by an onsetless syllable, while diphthong is considered to be in one single syllable. Examples for both are shown in (12) and (13). English hiatus is shown in (13). Two separate syllables create a sequence of vowels. The examples are *gooey* [gui] and *boa* [boɑ]. These appear in a single syllables, but are not diphthongs:

(12) Hiatus

```
σ σ
| |
CV V
```

(13) English Hiatus Examples

[gui]	'gooey'
[boɑ]	'boa'

The structure of English diphthong without hiatus is shown in (14). One syllable contains two vowel qualities. The examples are *boy* [boy] and *island* [aylɑnd].

(14) Diphthong

```
σ
|
VV
```

(15) English Diphthong Examples

[boy]	'boy'
[ayland]	'island'

When a phonological analysis is developed from the data that contains diphthongs, it is important to distinguish whether a diphthong is the result of hiatus or not. O'odham diphthongs are real diphthongs and not the result of hiatus. This is shown by secondary stress in O'odham (Fitzgerald 1997). In order to show how Tohono O'odham diphthongs are real, let us briefly look at the basic stress system in O'odham. Tohono

O'odham has stress on the first syllable. O'odham has secondary stress in the following conditions:

(16) Secondary Stress

a. when a monomorphemic word consists of more than three syllables. (σσσσ+)

b. when a polymorphemic word consists of three or more syllables. (σσ+σ)

For example, the monomorphemic trisyllable word *músigo* 'musician' has only one stress in the beginning because it consists of only three syllables.

(17) Monomorphemic Trisyllable Word

músigo 'musician'

A trisyllable that is polymorphemic receives secondary stress as shown in (18).

(18) Polymorphemic Trisyllable Word

múmsigò 'musicians'

The word is a plural form of *musigo*. The plural is formed by reduplication (see Chapter 1). Since a reduplicant is considered a separate morpheme, it receives secondary stress, when it becomes polymorphemic such as *múmsigò* 'musicians' due to reduplication. Note that stress clash is not allowed.

Let us turn to the discussion of how O'odham diphthongs are not the result of hiatus. Take the word *haiwañ* 'cow.' It is a disyllable word with a diphthong in the first syllable position. The stress is located on the first syllable *hai* due to a stress rule in the language that states the first syllable receives stress.

(19) Stress on Diphthong

σ	σ
hái	wañ

The second syllable *wañ* does not receive stress. As I mentioned earlier, the monosyllable with three or fewer syllables receives only one stress on the initial syllable position.

If this word is taken as a trisyllable with a hiatus [ai], as shown in (20a) the stress falls on the first syllable [ha]. The other two syllables [i] and [wan] do not receive stress because this is a monomorphemic word. Again, Tohono O'odham monomorphemic trisyllable words receive only one stress on the initial syllable position. An obvious trisyllable word *ʔaṣugal* 'sugar' is shown in (20b) for comparison. At this point, whether or not Tohono O'odham diphthong is due to hiatus is not yet clearly shown. The following, however, provides the discussion that diphthongs are true phonemes in Tohono O'odham.

(20) Stress on Hiatus

a.	σ́	σ	σ	b.	σ́	σ	σ
	há	i	wañ		ʔá	su	gal

As I mentioned before, a secondary stress appears when the word is polymorphemic and consists of three or more syllables. When this word becomes polymorphemic, such as *háiwañ-ga* 'someone's cow' with the plural reduplication, the word receives secondary stress on the third syllable. If the diphthong [ai] is the result of hiatus, the outcome should look like *háiwàn-ga* 'someone's cow' as shown in (21a). However, a stress assignment such as this is ungrammatical, and the true stress assignment is *háiwañ-gà*. As shown in (21a), the alienable possessive suffix [-ga] receives secondary stress. Because the first syllable is treated as a single diphthong, it behaves as one syllable. An obvious trisyllabic word, *ʔasugal* 'sugar', on the other hand, receives secondary stress on the third syllable when the suffix [-mad] is added, rather than the suffix.

(21) If Hiatus

	σ́ σ σ̀ σ	σ́ σ σ̀ σ
*	há i wàñ ga	ʔá ṣùgal-mad 'add sugar'

(22) If Diphthong

	σ́ σ σ̀
√	hái wañ gà

Hence it is confirmed that O'odham diphthongs are real diphthongs and not the result of hiatus (c.f. Fitzgerald 2000).[4]

3.1.6 Syllable Peripherals with Diphthongs

In this section, examples of syllables that have diphthongs with regards to onset and coda are shown. First, onset consonants with diphthongs are described. As discussed in Chapter 2, all syllables must have onset, including those containing diphthongs. Examples are shown in (23).

(23) Onset of Syllables with Diphthongs

[iu]	p**iu**	'sound an arrow makes'
[io]	k**io**hod	'rainbow'
[ia]	b**ia**	'dishout'
[ɨi]	b**ei**	'accept'
[ui]	k**ui**	'mesquite tree'
[oi]	h**oi**n	'greet'
[ai]	b**ai**k	'tail'
[ɨu]	h**iu**m	'to get cold'
[ɨo]	c**io**j	'boy'

[4] O'odham tends to avoid hiatus. Consider the examples in imperative formation:

The imperative suffix [-iñ] is attached to a verb to form an imperative verb.

čipkan	'work'	čipkan**iñ**
ñiok	'talk'	ñiok**iñ**

When verbs end in a vowel, however, the vowel [i] is dropped and no hiatus is examined.

čičwi	'play'	čičw**iñ**	* čičwi**iñ**	
kikiwa	'stand'	kikiwa**ñ**	* kikiwa**iñ**	Data from Zepeda (1983)

[ɨa]	ñɨal	‘visit expecting a gift or a meal’
[ua]	cua	‘grind’
[oa]	koa	‘forehead’
[au]	naupait	‘make wine’

The data in (24) show examples of each diphthong followed by a coda consonant. As stated in Chapter 2, any consonant except glottal consonants can be a coda.

(24) Coda of Syllables with Diphthongs

[iu]	hiwium	‘shave’
[io]	čioṣ	'to support oneself with a cane'
[ia]	miak	'near'
[ɨi]	ñɨid	'seeing'
[ui]	ǰuig	'to be full of prickly pear fruits'
[oi]	hoin	‘greet’
[ai]	baik	‘tail’
[ɨu]	hɨum	'to get cold'
[ɨo]	cɨoǰ	‘boy’
[ɨa]	ñɨal	‘visit expecting a gift or a meal’
[ua]	pualt	‘door’
[oa]	ṣoak	‘crying’
[au]	hauk	'to be light'

All syllables must have onsets, as established in Chapter 2. So, all syllables containing diphthongs must have onsets. Syllables can also have codas. Syllables containing all diphthongs can have coda.

Although all syllables containing diphthongs can have coda, these diphthongs seem to fall into two groups depending on their characteristics in weight. The division of the diphthongs is described in the following section.

3.2 Distribution Pattern of O'odham Diphthongs

There is an interesting distribution pattern to O'odham diphthongs. Among the diphthongs, some can occur in both stressed and unstressed syllable positions, and others occur only in stressed positions.

The following examples are words with diphthongs that can occur in both stressed and unstressed positions. These diphthongs are: /ai/, /ii/, /io/, /oi/, /ia/ and /ui/. The examples are shown in (25).

(25) Occur in Both Stressed/Unstressed Positions:

	stressed		unstressed	
/ai/	há**i**wañ	'cow'	hɨg**ai**	'that'
/ɨi/	ñ**ɨi**d	'seeing'	i:bh**ii**	'breath'
/io/	c**io**pi̥	'church'	káh**io**	'a leg'
/oi/	h**ói**n	'greet'	nón**oi**g	'stir'
/ia/	b**ia**	'dish out (food)'	cɨgg**ia**	'fighting'
/ui/	k**úi**	'tree'	ták**ui**	'soaptree/soapweed'
/iu/	p**iu**	'the allow sound'	hɨw**iu**m	'shave (the skin)'

They can appear in both stressed and unstressed positions. The next examples in (26) are words from the other group of diphthongs that only occur in stressed position. These diphthongs are: /au/, /oa/, /ua/ /ɨa/ /ɨo/ and /ɨu/.

(26) Occur Only in Stressed:

	stressed		unstressed
au	**náupait**	'make wine'	unattested
oa	**kóa**	'the forehead'	unattested
ua	**púalt**	'door'	unattested[5]
ɨa	**cɨ́a**	'hail, ice'	unattested
ɨo	cɨ́**oj**	'boy'	unattested
ɨu	**hɨum**	'to get cold'	unattested

The difference in the characteristics between the two groups that are shown above is clear when we look at the elements that comprise the diphthongs consist of. When [ɨ] is one of the elements of the diphthongs as in (25), it is revealed that diphthongs can occur in both stressed and unstressed positions. The position of the elements for [ɨ] does not matter. This [ɨ] can be the first element or second element of a diphthong in this group. On the other hand, diphthongs occur only in the stressed position, when they do not include [ɨ] as one of the two elements in their diphthongs as in (26). The difference between the two diphthong types with [ɨ] or without [ɨ] can be seen in an O'odham morphological system

[5] There is only one condition in which [ua] appears in an unstressed position; it is when [ua] is a variation of the suffix [wa], which means 'to do'. e.g. [wiḍwua (wiḍwa)] 'do stiring', [siswua (siswa)] 'do pitting'.

such as reduplication. Also, the characteristics of appearance in stressed and unstressed syllable positions are similar to those of other regular vowels such as short and long. This similarity is discussed in the following sections.

3.2.1 Comparison of Diphthongs and Monophthongs

There is another distinction between the two groups when we look at their phonological patterns. In this section, the comparison between diphthongs and monophthongs is shown. There are similarities between the first group of diphthongs and short vowels, as well as between the second group of diphthongs and long vowels. In Tohono O'odham, short vowels occur in both stressed and unstressed positions, whereas long vowels occur only in stressed positions.

(27) Short Vowels

Stressed	Unstressed
táko 'yesterday'	táko 'yesterday'

(28) Long vowels

Stressed	Unstressed
háaṣañ 'Saguaro cactus'	* háṣaañ

I make references to these two groups in terms of analogy to weight of monophthongs. I refer to *light diphthongs* for those diphthongs that behave like short vowels, and *heavy diphthongs* for those, that act like long vowels.

The table in (29) shows a comparison of diphthongs to short vowels and long vowels. I use V for representing a short vowel, VV for a long vowel, and V_1V_2 for a diphthong. All vowel types can appear in stressed position. In unstressed position, syllables that contain long vowels and heavy diphthongs do not appear.[6] This table (29) shows the type of vowels, as well as the number of moras in each vowel. The leftmost column lists the type of vowels: short vowel, long vowel, heavy diphthong and light diphthong. The next column gives the type of syllables: open vs. closed. Then the number of mora is shown in the next column. The last two columns indicate whether or not the syllable can be in stressed and/or unstressed position.

(29) **Vowel Type, Syllable Type and Stress**

		mora	stressed	unstressed
short	CV CVC	μ	yes hódai (rock) **čipkan** (working)	yes hí**mu** (one adj) bá**bad** (frog)
long	CVV CVVC	$\mu\mu$	yes káačim (above) **hiik** (navel)	no
L diph	CV_1V_2 CV_1V_2C	μ	yes háiwan (cow) **hial**wui (poison)	yes hódai (rock) wá**kial** (cowboy)
H diph	CV_1V_2 CV_1V_2C	$\mu\mu$	yes číadagi (Gila monster) **ñial** (visit)	no

[6] As I mentioned, monosyllabic words are all stressed but CV (short vowel) was not allowed because it does not satisfy the WdMin constraint. That is, CV is allowed if the whole word satisfies WDMIN (Because it has another moraic syllable).

The table in (30) is the simplified version of the table in (29). As this table (30) shows, short vowels appear in both stressed and unstressed positions. Long vowels only appear in the stressed position and they never appear in the unstressed position. Heavy diphthongs also appear only in the stressed position. Light diphthongs can appear in either position, just like short vowels. The rows of short vowel and light diphthongs are shaded in order to show the similarity between the two vowel types.

(30) Vowel Type and Stress

	stressed	unstressed
short vowel	yes	yes
long vowel	yes	no
heavy diphthong	yes	no
light diphthong	yes	yes

Thus, a short vowel and a light diphthong share a similarity in their behaviors. It is also clear that they are in the same weight category: monomoraic. Likewise, long vowels share weight with heavy diphthongs: they both are bimoraic. The analogy between diphthongs and monophthongs has been shown. Light vowels, short vowels and light diphthongs appear in both stressed and unstressed positions. Heavy vowels, long vowels and heavy diphthongs appear only in stressed position. The two types of diphthong differ in their weight as short vowels and long vowels do: monomoraic and bimoraic (Miyashita to appear).

3.2.2 Reduplication Pattern of Diphthongs

The two classes of diphthongs are also made clear from reduplication. Reduplication reveals another important fact regarding the classifications of the two groups of O'odham diphthongs.

Let us examine the reduplication pattern of light diphthongs first. O'odham words reduplicate in order to indicate plural or distributive forms for both nouns and verbs (see Ch2). As the examples in (31) show, light diphthongs, which can occur in both stressed and unstressed positions, keep the original form in the base. For example, the reduplicant repeats the first CV of the base form. So, *haiwañ* 'cow' reduplicates to *hahaiwañ*. Its reduplicant is the first CV *ha*. The base is the same as the original, *haiwañ*. When the reduplicant *ha* is attached to the base *haiwañ* as its prefix, the reduplicated form *hahaiwañ* is derived. In other words, diphthongs in the base form stay as diphthongs. The examples in (31) show the same effect. The diphthongs in the words stay the same in their reduplicated form.

(31) Light Diphthong:

	Base	Reduplicated	
/ai/	**háiwañ**	há**haiwañ**	'cow'
/ii/	**ñíid**	ñí**ñeid**	'see'
/io/	**pion**	pi**pion**	'employee'
/oi/	**hóin**	hó**hoin**	'move, stir'
/ia/	**bía**	bí**bia**	'to dish out obj.'
/ui/	**kúi**	kú**kui**	'tree'

Note that diphthongs in the base form are stressed, but they are in unstressed position in reduplicated form. This is possible because the light diphthongs can occur in both stressed and unstressed positions. The position of the diphthong /ai/ in *háiwañ* is stressed, but it is no longer in the stressed position in its reduplicated form *háhaiwañ*. Here, it is in the unstressed position.

Let us turn to the discussion of reduplication with heavy diphthongs. Heavy diphthongs reduplicate in a different manner from light diphthongs. Consider the data shown in (32). For example, *kóa* 'forehead' becomes *kóka* 'foreheads.' The diphthong [oa] is reduced to [a]. If it reduplicates as light diphthongs do, it would surface as *kókoa*, which is ill-formed. In other words, the diphthongs do not stay the same in reduplicated forms with heavy diphthongs. The form of a heavy diphthong is changed when it is reduplicated. The changed form is a single vowel, and it is the second element of the original diphthong.

(32) Heavy Diphthongs[7]

/au/	haupal	ha**hupal**	'red-tailed howk'
/oa/	koa	ko**ka**	'forehead'
	hoan	ho**han**	'search for'
/ua/	huaṣomi̥	hu**haṣomi̥**	'buckskin bag'
/ɨa/	čɨadagi	čɨ**čadagi**	'Gila monster'
/ɨu/	(unattested)		
/ɨo/	čɨoǰ	čɨ**coǰ**	'boy'
	ñɨok	ñɨ**ñok**	'talking'

If a heavy diphthong stays the same, such as *kókoa*, then the heavy diphthong would be in the unstressed position where heavy syllables are prohibited, causing a violation. The heavy diphthongs must be reduced into a segment that has only one mora in order to avoid paradox. By reducing a heavy diphthong into a monomoraic vowel, it can appear in unstressed position without violating the requirement of syllable position. In short, the reduplication process differs between the two groups of O'odham diphthongs.

3.2.3 Possible Analyses by Diphthong Quality

The clear structural difference between the two groups of diphthongs is the presence or absence of [i]. As I mentioned earlier, diphthongs which contain [i] are light, and they behave analogously to short vowels. Diphthongs which do not include [i] are heavy, and they behave analogously to long vowels. Therefore, the distinction seems to have something to do with the vowel quality of [i]. Although what I claim is that only

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[7] Again, there is no unstressed diphthong in this group.

the containment of the element [i] in a diphthong is required for it to be a light diphthong, some may want to analyze this element not as a vowel, but as a glide consonant [y] (c.f. Maddieson and Emmorey 1985). In this section, I show why this [i] in O'odham diphthongs should not be analyzed as the glide [y].

The vowel [i] is the key segment for a diphthong to be light. This segment can be either the first or the second element of the diphthong. One may assume that the reason why they are light is because this [i] is a non-moraic segment: possibly a glide consonant [y]. When the diphthong contains [i] as its second element such as [ai], the diphthong is thought of as the combination of a short vowel [a] and a glide [y]. For example, [ai] in the word *hegai* 'that' is actually [ay] in this case. That is, the glide [y] can be analyzed as a coda. On the other hand, when the first element of a diphthong is [i], it is a glide [y] and a vowel [a]. For instance, [ia] as in čiggia 'fighting' is actually [ya]. However, this is not a correct analysis, as I explain further.

The problem is revealed when we consider a codaless monosyllable with these diphthongs. As I have already mentioned in Chapter 2, a codaless monosyllable must have two moras, and therefore its vowel must be heavy.

(33) Codaless Monosyllable

```
CVV          CVC        * CVV
 | |   or     | |           V
 μ μ          μ μ           μ
```

Again, a content-word that is monosyllabic must have at least two moras, and a coda is required when the monosyllable word has a short vowel as its nucleus. But when a syllable has no coda, the vowel of the syllable must be long in order to satisfy the bimoraic requirement.

If the vowel [i] is a glide, we must consider the two occasions when it is the (i) first element, and the (ii) second element of a diphthong. When the vowel [i] is the first element of the diphthong such as [ya], it is incorrect to determine that this vowel is actually a glide [y]. If it is a glide, then this would be a part of onset for being the consonant [y]. However, an onset cannot carry a mora. That is, the requirement of bimoraicity must be satisfied by the weight of the vowel. Take for example the word *mia* 'near'. If the vowel [i] is analyzed as a glide consonant [y], then the word consists of the onset [my] and the vowel [a]. If the word consists of the onset [my] and the short vowel [a], then, following the notion of word minimality, the word cannot exist because the short vowel [a] is monomoraic (b), or the word must have a long vowel in order to satisfy the word minimality requirement (c). However, the word does exist and no vowel lengthening is seen as shown in (34) below.

(34) No Lengthening

a.	mia	b.	* mya	c.	* myaa
	||		|		||
	$\mu\mu$		μ		μ μ

Also, an O'odham onset is restricted to a single consonant in order to avoid the violation of *COMPONS (Chapter 2). Because of this, a word like [mya] with two consonants in onset is not possible. Thus, there is no convincing reason to claim that [i] is actually a glide consonant [y]. The element [i] in the light diphthong is not a consonant.

Let us consider the other case when [i] is the second element of a diphthong. With the glide analysis, a word like [kui] can be analyzed as [kuy]. In Tohono O'odham, CVC is actually a possible syllable form. However, as I have already mentioned, the first element [i] cannot be [y], and if we consider the [i] to be [y] in the second element, the status of the element [i] must have two different properties. That is, [i] is the vowel when it is the first element of a diphthong and a consonant when it is the second element. It is more plausible to treat this element as if both were vowels or consonants. However, they cannot both be analyzed as consonants. Again, O'odham onsets cannot have two consonants, and therefore, the element [i] is the vowel [i], and a light diphthong is a diphthong that contains [i] as its elements, not one that contains [y].

3.3 Moraicity Descriptions and Generalizations

In this section, I look at moraic structure of words including diphthongs. In the previous sections, I mentioned that O'odham diphthongs can be divided into two categories: heavy and light. I explain the moraicity of these two groups in depth in the following sections.

3.3.1 Diphthong Weight Variations

As I mentioned above, light diphthongs and heavy diphthongs differ in moraicity. A light diphthong is monomoraic, and a heavy diphthong is bimoraic. However, there is one condition under which a light diphthong becomes bimoraic. This change in moraicity must be accounted for. And it was not well explained with the account using the glide consonant [y] instead of the vowel [i] as I mentioned earlier.

A light diphthong becomes heavy when it appears in a codaless monosyllable. An O'odham content-word must be at least bimoraic. A monosyllabic word without coda must have a heavy vowel in order to satisfy this requirement. For example, the weight of a word with a light diphthong as in *kai* must be bimoraic, suggesting that the diphthong is heavy.

(35) Diphthongs and Mora

kai	* kai
|	|
$\mu\mu$	μ

For example, (37)a [ñɨid] 'seeing' becomes [ñɨi] 'saw' when it is truncated, as shown below. The last consonant [d] dissapears but the vowel [ɨi] remains the same. However, if light, Compensatory Lengthening (Hayes 1989) should occur. Yet, there is no Compensatory Lengthening seen in the process of truncation with a diphthong. Thus light diphthongs are bimoraic in this context.

(36) Truncation with Long Vowels:

	Imperfective		Perfective	
a.	hiik	'cutting'	hii	'cut'
b.	ǰɨɨk	'tasting obj.'	ǰɨɨ	'tasted something'
c.	čuuk	'stopping burning'	čuu	'stopped burning'
d.	ṣoom	'sewing'	ṣoo	'sewed'
e.	maak	'giving'	maa	'gave'

(37) **Truncation with Light Diphthongs:**

	Imperfective		Perfective	
a.	ñɨ́id	'seeing'	ñɨ́i	'saw'
b.	hóin	'moving'	hói	'moved'
c.	háin	'cracking'	hái	'cracked'
d.	'óid	'follow, accompany'	'ói	'followed, accompanied'

(38) **Truncation with Heavy Diphthongs:**

	Imperfective		Perfective	
a.	ñɨ́ok	'talking'	ñɨ́o	'talked'
b.	hóan	'searching for'	hóa	'searched for'
c.	ñɨ́ad	'beg from'	ñɨ́a	'begged from'
d.	ñɨ́al	'visit expecting a gift'	ñɨ́a	'visited expecting a gift'
e.	hɨ́ot	'bloom, produce flowers'	hɨ́o	'bloomed, produced flowers'

As shown in the examples (36) – (38), all categories, long vowels, light diphthongs and heavy diphthongs behave the same way when they are monosyllables in truncation. It is shown that light diphthongs, which are monomoraic, appear as heavy or bimoraic in codaless monosyllables.

3.3.2 Two Classes

As discussed above, there are two different types of diphthongs in Tohono O'odham. In this section, these two patterns are classified as Class L and Class H, as shown in (39) below. Class L words contain light diphthongs and short vowels. These are monomoraic members. Class H contains heavy diphthongs and long vowels. They are bimoraic. This classification (39) is used in the OT analysis.

(39) Vowel Types and Moraicity

Class	Mora	Members
Class L	μ	contains a light diphthong, short vowel
Class H	$\mu\mu$	contains a heavy diphthong, long vowel

3.3.3 Summary

Diphthongs are divided into two groups. One group consists of light diphthongs, and these diphthongs include [i] in the element consisting of the diphthong. They are monomoraic. The other is heavy diphthongs and neither element is [i]. They are bimoraic. The groups differ in the reduplication pattern and the distribution regarding stress assignment. The light diphthongs can appear in both stressed and unstressed positions, while heavy diphthongs occur only in stressed positions. Light diphthongs are bimoraic only when they are monosyllables with no coda. These two groups are categorized as Class L and Class H. Class L contains monomoraic elements: short vowels, light diphthongs. Class H contains bimoraic members: long vowels and heavy diphthongs. In the following sections, OT analyses are presented.

3.4 Optimality Theory

In this section, weight of Tohono O'odham diphthongs is accounted for in terms of OT. Fitzgerald (1997) makes an OT analysis for prediction of primary and secondary stress of both monomorphemic and polymorphemic in O'odham. Her analysis does not require the specification of weight, but she assumes that codas are moraic. In my analysis, the weight of diphthong depends on its vowel type: light or heavy as shown in the earlier sections. I analyze the weight of O'odham syllables in terms of OT regarding these two vowel classes.

3.4.1 Previous Work the Stress Account

The previous work shown in (40) treats the stress assignment of O'odham words. However, weight assignment is ignored although it is assumed that O'odham is sensitive in quantity. I show an example tableau with the previous analysis.

Before moving on to the example tableau, let me briefly explain the constraints and the ranking proposed by Fitzgerald (1997). The definitions are as follows (Fitzgerald 1997)[8]:

[8] There are other constraints that appear in the literature, but I use only the ones relevant to my dissertation.

(40) Constraints in Fitzgerald (1997)

a. *CLASH: Adjacent stresses are not permitted.

b. FOOTFORM (abbreviated FTFM): Heads are on the left edge of the foot

c. *LAPSE *W(: Avoid an unfooted syllable (WEAK) followed by a footed syllable.

d. MORPHEME -TO-STRESS PRINCIPLE(MSP): For every morpheme, there exists some stressed syllable that falls in the domain of that morpheme.

e. FootBinarity (FtBin): Feet are analyzable as binary on the syllable level.

*CLASH is high ranked since stressed syllables do not occur adjacently. FTFM is ranked high because this motivates initial stress on a word. *LAPSE is used in order to exclude a lapse in a word. MPS is proposed by Fitzgerald (1997) and it shows the relationship between morphemic structure and stress. The ranking is shown in (41). *CLASH and FTFM dominate *LAPSE, *LAPSE dominates MSP, and MSP dominates FTBIN.

(41) The Ranking

*CLASH, FTFM >> *LAPSE >> MSP.

In the tableau below, I use the word haiwañ 'cow' since it includes a diphthong [ai] and a coda [ñ]. The word boundary is indicated by square brackets [ ], and the foot boundary by parentheses ( ). Candidate (a) is the optimal output. This candidate does not violate any of the four constraints in the tableau. There is no stress clash (*CLASH), the stress is left headed (FTFM), no unstressed syllable is in the left of a left foot bracket (*LAPSE), and the morpheme has a stress (MSP). Candidate (b) is ruled out because it has two stressed syllables next to each other, resulting in a stress clash. Candidate (c) violates FTFM due to its headedness and is not correct. Candidate (d) violates *LAPSE because the unfooted syllable /hai/ is in the left side of the footed syllable /(wañ)/. Candidate (e) violates MSP by having no stress. Finally, candidate (f) violates FTBIN. Therefore, Candidate (a) is selected.[1]

(42) ***haiwañ* 'cow'**

		*CLASH	FTFM	*LAPSE	MSP	FTBIN
☞ a.	([háiwañ])					
b.	([hái)(wáñ])	*!				
c.	([haiwáñ])		*!			
d.	[hai(wáñ])			*!		
e.	[haiwañ]				*!	
f.	([hái)wan]					*!

This analysis is serves the purpose of accounting for the stress assignment. However, the moraicity in syllables is not indicated in the tableau (42). There are several possible candidates that have the same stress assignment as candidate (a) but with different moraicity. This causes the problem of not being able to select one candidate as shown in (43). The mora is indicated by subscripted μ on the right hand side of each segment. There are four candidates represented but they are basically derived from the same form:

[1] STRESS-TO-MORPHEME PRINCIPLE is ranked between FTFM and *LAPSE. I omit this constraint because this is effective to non-optimal candidate that has an epenthetic vowel (see Fitzgerald 1996). I do not use a word with epenthesis, so this constraint is not applicable to this dissertation.

candidate (a), the winning output in (42) above. Since all of them satisfy the constraints, none violates any of the constraints shown although each of them is different in their mora assignment.

(43) ***haiwañ*** **'cow'**

		*CLASH	FTFM	*LAPSE	MSP	FTBIN
☞ a.	([hái$_{\mu}$wa$_{\mu}$ñ])					
☞ b.	([hái$_{\mu\mu}$wa$_{\mu}$ñ])					
☞ c.	([hái$_{\mu}$wa$_{\mu}$ñ$_{\mu}$])					
☞ d.	([hái$_{\mu\mu}$wa$_{\mu}$ñ$_{\mu}$])					

According to the generalization given earlier, this diphthong [ai] in the first syllable is a light diphthong and the coda [ñ] is moraless. That is, candidate (a) must be the optimal one. However, selection of this optimal candidate is impossible at this stage. There is no way to select it with these constraints and the ranking. In the following sections, the evaluation of words with diphthongs with moraic theory is presented.

3.4.2 Class L: OT Analysis

In this section, I provide an analysis of Class L vowels. Class L vowels consist of a short vowel and a light diphthong. A light diphthong contains [i] as one of the two elements. The properties to be accounted for are given as the generalization in (44). The generalization for Class L is:

(44) Generalization of Class L:

Class L vowels are monomoraic.

As shown in the previous chapter, a short vowel becomes bimoraic (a long vowel) in a codaless monosyllable word in order to satisfy Word Minimality. In the same way, a light diphthong becomes bimoraic when it appears in a codaless monosyllable.
The interesting fact that, even though a light diphthong is mornomoraic, it surfaces as bimoraic in a codaless monosyllable word, is accounted for in terms of OT. I use the four words shown in (45) below. [kui] 'tree' to show that this becomes heavy in a codaless monosyllable, [hodai] 'rock' to show light diphthongs in unstressed syllables, [haiwañ] to show light diphthongs in a stressed syllable, and [tako] 'yesterday' to show short vowels. In addition, I include a monomoraic codaless monosyllable in order to show that such words could never be optimal in Tohono O'odham. this discussion appears after the evaluation of the monosyllable [kui].

(45) <u>Words Used</u>

kúi	'tree'	(monomoraic light diphthong becomes bimoraic)
		VV_{μ} -> $VV_{\mu\mu}$
hódai	'rock'	(monomoraic light diphthong, unstressed)
háiwañ	'cow'	(monomoraic light diphthong, stressed)
táko	'yesterday'	(monomoraic stressed and unstressed)

The first two constraints have already been introduced. Additionally, the MINIMALWORD constraint forces a candidate to satisfy bimoraic minimality. And I use the FOOTFORM constraint as Fitzgerald states. This controls a word being initially stressed, and the foot forms such as (σ́) and (σ́σ) are predicted, but (σσ́) is ruled out. These constraints are defined in (46) and (47) below.

(46) **MINIMALWORD (MINWD):**

A word must be at least bimoraic (Fitzgerald and Fountain 1997).

(47) **FOOTFORM (FTFM):**

Heads are on the left edge of foot.

3.4.2.1 Class L: Long Vowel in a Codaless Monosyllable

The evaluation of [kui] 'tree', a codaless monosyllable, is shown in (48) below. The diphthong in the word is heavy and stressed. Candidate (a) is a stressed bimoraic syllable, and satisfies both constraints while the other two violate one or both constraints. Candidate (b) is monomoraic and thus violates MINWORD. However, it satisfies FTFM. The last candidate is not stressed and violates FTFM for lacking its head. The ranking of the two constraints is not crucial at this point.

(48) kúi **'mesquite tree': Class L , light diphthong**

	/kui/	MINWD	FTFM
☞ a.	(kúi$_{\mu\mu}$)		
b.	(kúi$_{\mu}$)	*!	
c.	(kui$_{\mu\mu}$)		*!

3.4.2.2 Class L: a Short Vowel in a Codaless Monosyllable

A codaless monosyllable with a short vowel does not occur in Tohono O'odham. The following tableau (49) is an evaluation of this type. Although Tohono O'odham does not have such a word, it is necessary to make a prediction with this type, because it can show the nature of O'odham phonological properties. The input has the form of codaless monosyllable with a short vowel. The optimal candidate should be bimoraic and not monomoraic. In the tableau below, candidate (a) satisfis both. Candidate (b) is ruled out because it violates MINWD for not having two moras. Candidate (c) satisfies MINWD but not FTFM for lacking its head. Candidate (d) satisfies both constraints, but this should be excluded for adding a new vowel quality (a). Although the correct output is only one, candidate (a), the point made here is that a bimoraic word is selected as an optimal output from monomoraic codaless monosyllable input.

(49) **_kú_, Class L , short vowel, nonsense word**

	/ku/	MINWD	FTFM
☞ a.	(kú$_{\mu\mu}$)		
b.	(ku$_{\mu}$)	*!	
c.	(kui$_{\mu\mu}$)		*!
💣 d.	(kúa$_{\mu\mu}$)		

Further evaluation is made by the use of a Faithfulness constraint. The crucial difference between the two winning candidates (a) and (d) in (49) above is the quality of the vowels. Candidate (a) keeps the same vowel quality as in the input, which is [u]. Candidate (d) has a vowel quality [a] which is not found in the input. Since the candidate that has a vowel not contained in the input must be ruled out, and because the candidate that does not have any vowel segment not represented in the input must be selected, FAITH(V) is motivated. This problematic candidate (d) is ruled out by the FAITH(V) constraint:

(50) FAITH(V):

The vowel quality in input and output is the same.

The evaluation is shown in the tableau (51):

(51) kú, Class L , short vowel

	/ku/	MINWD	FTFM	FAITH(V)
☞ a.	(kú$_{\mu\mu}$)			
b.	(kú$_{\mu}$)	*!		
c.	(kui$_{\mu\mu}$)		*!	
d.	(kúa$_{\mu\mu}$)			*!

Candidate (d) violates FAITH(V), and therefore candidate (a) is the optimal output. This optimal candidate selected in the tableau above is not attested in O'odham. However, nothing prevents this unattested word *kuu* to be illegal. As shown from the existing O'odham words such as *huu* 'to eat obj.' and *kuukun* 'husband', the long vowel [uu] is allowed in a codaless monosyllable word, and the sequence of [k] and [uu] is also presumably allowed. Although Tohono O'odham does not have the word *kuu*, it is generated as possible Tohono O'odham word. The lack of this word is not explained by the ill-formedness. That is, the word *kuu* can exist as a well-formed O'odham word when it has a semantic association.

Let us turn to the evaluation of Class L vowel in a codaless monosyllable. The constraints and the ranking are shown in (52) below. All are ranked equally with each other.

(52) Constraint and Ranking so far:

MINWRD, FTFM, FAITH(V)

3.4.2.3 Class L: Unstressed Diphthong

In this section, an evaluation of a disyllable, [hódai] 'rock' is presented. The tableau (53) shows the evaluation of the word with the three constraints shown (52). All candidates satisfy MINWD. Candidate (b) violates FTFM for having its head in the wrong position, and candidate (c) violates FAITH(V) for having a vowel that is not in the input. Candidate (d) and (e), however, satisfy all constraints and incorrectly win.

(53) *hódai*, 'rock': Class L

	/hodai/	MW	FTFM	FATH(V)
☞.a.	(hó$_\mu$.da$_\mu$i)			
b.	(ho$_\mu$.dá$_\mu$i)		*!	
c.	(hó$_\mu$a$_\mu$.da$_\mu$i)			*!
💣 d.	ho$_\mu$.(dá$_\mu$i)			
💣 e.	(hó$_\mu$.da$_\mu$i$_\mu$)			

The problem of having the two incorrectly winning candidates (d) and (e) is solved in through the following process. First, candidate (d) is ruled out by *LAPSE, which is defined in (54) below.

(54) *Lapse or *W(:

Avoid an unfooted syllable followed by a footed syllable (Fitzgerald 1997).[2]

Tableau (55) shows the evaluation with this constraint. Candidate (a) is selected because it does not violate both constraints FTFM and *LAPSE. Its foot structure is bimoraic and left headed. Candidate (b) violates FTFM because its head is on the right of the foot. Candidate (d) violates *Lapse because the unfooted syllable is followed by a footed syllable.[3] The ranking is still not crucial.

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[2] This can be also solved with the use of Align when it is defined that a left of a foot and a left edge of a word must be aligned. Fitzgerald claims that *LAPSE takes care of the align constraint and correct evaluation can be seen without a presence of Align. I adopt her analysis and use *Lapse without Align in my dissertation.

[3] This candidate (d) is also ruled out by FtBin (cf. Fitzgerald 1997). However, it is crucial to eliminate a candidate with an initial unfooted syllable. Otherwise, a word like *kákaiču* 'a quail' will not be ruled out only by FtBin because it can form a internal structure such as *ka(káiču)*, which satisfies FtBin.

(55) ***hódai*, 'rock': Class L**

	/hodai/	MW	FTFM	FAITH(V)	*LAPSE
☞ a.	($hó_{\mu}$.da_{μ}i)				
b.	(ho_{μ}.$dá_{\mu}$i)		*!		
c.	($hó_{\mu}a_{\mu}$.da_{μ}i)			*!	
d.	ho_{μ}.($dá_{\mu}$i)				*!
💣 e.	($hó_{\mu}$.$da_{\mu}i_{\mu}$)				

The remaining incorrectly winning candidate (e) should fail. The difference between the two winning candidates (a) and (e) is the number of moras in the diphthong [ai]. Candidate (a) has one mora and the incorrect candidate (e) has two moras. This difference must be accounted for. A vowel always has at least one mora. That is, it is predictable that a vowel has at least one mora. When a phonological phenomenon is predictable, it means that this phenomenon must be accounted for. In terms of OT, being accounted for means to be evaluated with constraints and ranking, and not by positing that the phenomenon is a property of the input. It is predictable that vowels are moraic, so there must be a constraint that tells candidates to have one mora in a vowel. Such a constraint is required and I introduce the MORAINDISPENSABILITY (MI) constraint, which is defined in (56) below:

(56) **MORAINDISPENSABILITY (MI):**

A vowel must have at least one mora.

This constraint ruled out a candidate with a vowel that has no mora. According to this constraint, each element of diphthong must be treated as one vowel.[4] Hence, a diphthong is bimoraic due to the nature of this constraint. An example evaluation with this constraint is shown in (57). Candidates (a) and (d) violate this constraint once because they lack a mora on the second vowel element in the diphthong [ai]. Candidate (e) satisfies it because the diphthong [ai] is bimoraic. However, a wrong candidate (e) wins. This is because the correct candidate (a) violates MI, while incorrect candidate (e) does not.

(57) ***hódai*, 'rock': Class L**

	/hodai/	MW	FTFM	FAITH(V)	*LAPSE	MI
☞ a.	(hó$_\mu$.da$_\mu$i)					*!
b.	(ho$_\mu$.dá$_\mu$i)		*!			*
c.	(hó$_\mu$a$_\mu$.da$_\mu$i)			*!		*
d.	ho$_\mu$.(dá$_\mu$i)				*!	*
💣 e.	(hó$_\mu$.da$_\mu$i$_\mu$)					

Although mora assignment is accounted for, another constraint is required because the incorrect candidate is still winning. In order for the correct candidate (a) to win over the incorrect one, a constraint that (a) satisfies but (e) fails must be ranked higher than MI. Such a constraint must rule out a candidate with a light diphthong being bimoraic in unstressed position. What is happening is that the light diphthong [ai] is bimoraic in

[4] A long vowel is not determined by this constraint. A long vowel is lexically contrasted with a short vowel, and the moraicity of a long vowel must be indicated in the input.

candidate (e) although it has to be monomoraic because the diphthong is light, being in the unstressed position. I introduce a new constraint that accounts for the problem in (58) below.

(58) **POSITIONALDIET (PD)[5]:**

In an unstressed syllable position, among two vowels in a diphthong, a high front vowel [i] carries no weight when the other element is non-identical.

This constraint now solves the problem as shown in (59). The correct candidate (a) does not violate PD because the second element of the diphthong [ai] does not have mora. While candidate (e), which was the incorrectly winning candidate in the previous tableau (57), violates PD for having mora on the second element [i] in the diphthong.

(59) ***hódai*, 'rock': Class L**

	/hodai/	MW	FTFM	FAITH(V)	*LAPSE	PD	MI
☞ a.	(hó$_\mu$.da$_\mu$i)						*
b.	(ho$_\mu$.dá$_\mu$i)		*!				*
c.	(hó$_\mu$a$_\mu$.da$_\mu$i)			*!			*
d.	ho$_\mu$.(dá$_\mu$i)				*!		*
e.	(hó$_\mu$.da$_\mu$i$_\mu$)					*!	

[5] The high front vowel [i] is also a salient member among vowels regarding devoicing, supporting the weight loss analysis.

PD must be ranked higher than MI. If the two constraints switch their ranks, an incorrect evaluation will occur as shown in (60).

(60) ***hódai* 'rock': Class L**

	/hodai/	MinWd	FtFm	Faith(V)	*Lapse	MI	PD
☞ a.	(hó$_\mu$.da$_\mu$i)					*!	
b.	(ho$_\mu$.dá$_\mu$i)		*!			*	
c.	(hó$_\mu$a$_\mu$.da$_\mu$i)			*!		*	
d.	ho$_\mu$.(dá$_\mu$i)				*!	*	
💣 e.	(hó$_\mu$.da$_\mu$i$_\mu$)						*

Therefore, PD must dominate MI as shown in (61).

(61) **PD >> MI**

This PD constraint must be ranked lower than MinWd. If this constraint is ranked above MinWd, the evaluation of monosyllabic word is incorrectly evaluated as shown in (62). Candidate (a) fails for violating PD, although this is the correct candidate.

(62) ***kúi* 'mesquite tree' : Class L, Light Diphthong**

	/kui/	PD	MinWd
a.	(kú$_\mu$i$_\mu$)	*!	
💣 b.	(kú$_\mu$i)		*

When MINWD outranks PD, the candidates are correctly evaluated as shown in (63).

(63) *kúi* 'mesquite tree' : Class L, Light Diphthong

	/kui/	MINWD	PD
☞ a.	(kú$_{\mu}$i$_{\mu}$)		*
b.	(kú$_{\mu}$i)	*!	

Therefore, PD must be ranked lower than MINWD. The resulting constraints and their ranking now are shown in (64). The crucial point is that MINWD outranks PD, and PD outranks MI. All other candidates are equally ranked with MINWD.

(64) Constraints and Ranking

{ MINWD, FTFM, *LAPSE, FAITH(V) } >> PD >> MI

3.4.2.4 Mora Specification in Input

When input carries moras such as /hoda$_{\mu}$i$_{\mu}$/, the optimal output is predicated to be [ho$_{\mu}$dá$_{\mu}$i$_{\mu}$]. This is how exceptionally stressed words are analyzed. An analysis of exceptionally stressed words is presented in a later section.

3.4.2.5 Class L: Stressed Diphthongs

Since light diphthongs are monomoraic except when they are in codaless monosyllables, one might claim that a light diphthong [ai] in a word like *haiwañ* must be monomoraic unless it is a codaless monosyllable as previously demonstrated. There is no reason for the light diphthong to be bimoraic in a disyllable word. However, as I mentioned earlier, the PD constraint works only for unstressed syllable positions. That is, a stressed light diphthong is not relevant to the PD constraint. The vowel will have two moras due to MI. This analysis is shown in tableau (65) with the evaluation of *háiwañ* 'cow'. The diphthong is light and stressed. Candidate (a) wins, not violating any constraint. Its head is on the left edge of foot, there is no unfooted syllable that triggers *LAPSE. This candidate does not violate PD because there is no light diphthong that is in an unstressed position. It vacuously satisfies the PD constraint, and therefore this candidate (a) wins. Candidate (b) violates FTFM because its head is not at the left edge of the foot. Candidate (c) violates *Lapse. Candidate (d) violates MI once for lacking a mora on [i].

(65) *háiwañ* 'cow' : Class L, stressed diphthong

	/haiwañ/	MW	FTFM	FAITH(V)	*LAPSE	PD	MI
☞ a.	(há$_\mu$i$_\mu$.wa$_\mu$ñ)						
b.	(ha$_\mu$i.wá$_\mu$ñ)		*!				*
c.	ha$_\mu$i.(wá$_\mu$ñ)				*!		*
d.	(há$_\mu$i.wa$_\mu$ñ)						*!

3.4.2.6 Class L: Short Vowels: disyllables

In the case of short vowels in a disyllable, their evaluation is presented in tableau (66). The optimal candidate is (a). It satisfies all constraints. Candidate (b) violates MINWD and MI for lacking a mora on the second vowel. Candidate (c) fails to have an optimal foot form, hence violates FTFM. Candidate (d) also fails because it violates FAITH(V) for having a vowel [i], which is not in the input. And candidate (e) violates *LAPSE for not avoiding the scenario of an unfooted syllable being followed by a footed syllable. The evaluation is complete at this point, and candidate (a) is the optimal output.

(66) *táko* 'yesterday': Class L, short vowel.

	/tako/	MW	FTFM	FAITH(V)	*LAPSE	PD	MI
☞ a.	(tá$_\mu$.ko$_\mu$)						
b.	(tá$_\mu$.ko)	*!					*
c.	(ta$_\mu$.kó$_\mu$)		*!				
d.	(tá$_\mu$i.ko$_\mu$)			*!			*
e.	ta$_\mu$.(kó$_\mu$)				*!		

Thus these constraints can account for the moraic structure of Class L diphthongs. The current ranking is the same as what has been shown in (64). It is shown in (67) again.

(67) Constraints and Ranking

$$\left\{ \begin{array}{l} \text{MinWd} \\ \text{FtFm} \\ \text{*Lapse} \\ \text{Faith(V)} \end{array} \right\} \gg \text{PD} \gg \text{MI}$$

3.4.3 Class H: OT Analysis

In this section, OT analysis of Class H vowels is provided. Class H members are long vowels and heavy diphthongs. They are bimoraic, and never appear in unstressed position. The generalization is given in (68):

(68) Generalization of Class H Vowels:

Class H members, long vowels and heavy diphthongs are bimoraic.

They appear only in stressed syllable position.

I use the words in (69) to show the evaluation of words with Class H vowels.

(69) <u>Word Used</u>

kóa	'forehead'	(a hyavy diphthong in a monosyllable)
dóakag	'one's life'	(a heavy diphthong in a disyllable)
kíi	'house'	(a long vowel in a monosyllable)
míisa	'table'	(a long vowel in a disyllable)

3.4.3.1 Class H: Diphthongs in a Codaless Monosyllable

The evaluation of codaless monosyllables is similar to the evaluation of [kui] with the light diphthongs [ui] shown in the previous section. The evaluation of a word with a heavy diphthong is shown in tableau (70). Candidate (a) does not violate any constraint, and is thus the optimal candidate. Candidate (b) violates MINWD for having only one mora. Candidate (c) also violates MINWD for not having any mora. These two candidates violate MI as well as MINWD. However, since MINWD is ranked higher, so the violation of MI is not significant, and candidate (d) lacks stress, hence it violates FTFM. FAITH(V) is omitted and there are no candidates that violate it. Therefore, candidate (a) wins.

(70) kóa 'forehead' Class H

	/koa/	MW	FTFM	*LAPSE	PD	MI
☞ a.	($kó_{\mu}a_{\mu}$)					
b.	($kóa_{\mu}$)	*!				*
c.	(kóa)	*!				**
d.	($ko_{\mu}a_{\mu}$)		*!			

3.4.3.2 Class H: Heavy Diphthongs in a Disyllable

The evaluation of disyllables is shown in this section. Consider the tableau in (71). All candidates satisfy MINWD because they have at least two moras. Candidate (a) does not violate any constraint. Candidate (b) violates FTFM, for its head is on the right edge. Candidate (c) fails for violating *LAPSE. Candidate (d) violates MI because the second syllable contains a moraless vowel. Candidate (e) violates MI for not having a mora on the vowel [o] of the diphthong [oa]. Candidate (f) fails for violating P-(σ). Therefore candidate (a) wins, which is the correct output.

(71) ***dóakag*** **'life, a soul': Class H**

	/doakag/	MW	FtFm	*Lapse	PD	MI	P-σ
☞ a.	(dó$_\mu$a$_\mu$.ka$_\mu$g)						
b.	(do$_\mu$a$_\mu$.ká$_\mu$g)		*!				
c.	do$_\mu$a$_\mu$.(ká$_\mu$g)			*!			*
d.	(dó$_\mu$a$_\mu$.kag)					*!	
e.	(dóa$_\mu$.ka$_\mu$g)					*!	
f.	(dó$_\mu$a$_\mu$).kag						*!

3.4.3.3 Class H: Long Vowel, Monosyllable

The evaluation of a monosyllable with a long vowel is the same as the evaluation of a monosyllable with a heavy diphthong, except that the input carries moras. As I claimed in Chapter 2, non-predictable moras are indicated in the input. In tableau (72), candidate (a) is the winner. It satisfies all constraints. Candidate (b) fails because it violates MinWd for having only one mora. Candidate (c) also violates MinWd for not having any mora. And candidate (d) lacks head and so violates FtFm. Hence candidate (a) wins.

(72) **kîi 'house' Class H, Long Vowel, Monosyllable**

	/$ki_{\mu\mu}$/	MW	MAX(μ)	FTFM	*LAPSE	PD	MI
☞ a.	($kí_{\mu\mu}$)						
b.	($kí_{\mu}$)	*!	*				
c.	(kí)	*!	*				**
d.	($ki_{\mu\mu}$)			*!			

There is another constraint represented in the tableau (72): MAX(μ). It is defined in (73):

(73) **MAX(μ):**

Any mora in the input is maximized in the output.

Its importance in the evaluation of monosyllable is not yet shown because MINWD excludes the same candidates that violate MAX(μ). The necessity of this constraint for the evaluation of disyllables with long vowels is shown in the next section

3.4.3.4 Class H: Long vowel in a disyllable

The evaluation of a disyllable with a long vowel is shown in the tableau (74). Candidate (a) is the optimal candidate. It satisfies all the crucial constraints. Candidate (b) is ruled out because it violates FTFM. Candidate (c) is also ruled out because it violates *LAPSE. Candidate (d) fails because it violates MI for not having any mora in the second syllable. Candidate (e) is ruled out for violating MAX(μ). This is where the necessity of MAX(μ) is shown. Since the mora in the input is not maximized in candidate (e), it is excluded from the competition. Candidate (f), lastly, is ruled out for violating P-(σ).

(74) ***miisa* 'table' Class H, long vowel, disyllable**

	/mi$_{\mu\mu}$sa/	MW	MAX(μ)	FTFM	*LAP	PD	MI	P-σ
☞ a.	(mí$_{\mu\mu}$.sa$_{\mu}$)							
b.	(mi$_{\mu\mu}$.sá$_{\mu}$)			*!				
c.	mi$_{\mu\mu}$.(sá$_{\mu}$)				*!			*
d.	(mí$_{\mu\mu}$.sa)						*!	
e.	(mí$_{\mu}$.sa$_{\mu}$)		*!					
f.	(mí$_{\mu\mu}$).sa$_{\mu}$							*!

The constraints and the ranking are shown in (75) below.

(75) **Constraints and Ranking**

{ MinWd, Max(μ), FtFm, *Lapse, Faith(V) } >> PD >> MI >> P-(σ)

3.5 Extension: Non-native Pattern

In the previous sections, I have shown OT analyses of the following cases:

(76) OT Analysis So Far

a. Class L:

i. short vowel

initial position (stressed)

non-initial position (unstressed)

ii. light diphthong

initial position (stressed)

non-initial position (unstressed)

b. Class H:

i. long vowel

initial position (stressed)

ii. heavy diphthong

initial position (stressed)

The analysis of heavy diphthong and long vowels in non-initial position is not yet presented. In this section, I explore the evaluation of irregularly stressed words. The term irregularly or exceptionally stressed in O'odham means that a word holds a stress on a non-initial syllable. These irregularly stressed words are usually borrowed words from Spanish (Moll 1997).[1] As I have shown, regular stress assignment is motivated by the

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[1] Not all borrowed words are irregularly stressed. For example, *mîisa* 'table' is from Spanish *mésa*. The stress is still in the initial position. The original Spanish *mésa* is stressed on the initial syllable. When the words in the original language have initial stress, the words in O'odham will also have initial stress. Hence

align constraint. When a word has irregular stress assignment, it is solved by the faithfulness of mora between input and output in O'odham.

Within the group of non-native stressed words, stress falls onto a non-initial syllable. The stressed syllable interestingly always containings Class H vowels and any other diphthongs. That is, distinction between Class L and H amongst diphthongs no longer matters. This heaviness of the non-initial stressed syllable must simply be learned. It is always CVV(C) and not CVC. Since O'odham coda is not moraic, non-initial CVC is not considered to be a heavy syllable in general. In (77), the words have stress on their non-initial syllable. The position of the stressed syllables is not consistent. Stress can be on the second syllable of a disyllable (a). It can also be on the second syllable of a trisyllable (b) – (e), or it can be on the third syllable of a trisyllable (f). But the stressed syllable is always long. In other words, stressed syllables are heavy.

(77) **Long Vowels**

	O'odham		gloss	Spanish
a.	pastíil	$\sigma\acute{\sigma}_{\mu\mu}$	'a pie'	< pastél
b.	asúuga	$\sigma\acute{\sigma}_{\mu\mu}\sigma$	'sugar'	< azúcar
c.	kalsíida	$\sigma\acute{\sigma}_{\mu\mu}\sigma$	'sock'	< calzádo
d.	minúuto	$\sigma\acute{\sigma}_{\mu\mu}\sigma$	'a minute'	< minúto
e.	añíilmagi̥	$\sigma\acute{\sigma}_{\mu\mu}\sigma$	'green'	< añíl
f.	gasolíin	$\sigma\sigma\acute{\sigma}_{\mu\mu}$	'gasoline'	< gasolína

---

not all borrowed words have non-initial stress. However, traditional O'odham words are always stressed on the initial syllable.

Also, a vowel of a stressed syllable can be a diphthong. In the case of exceptionally stressed syllables, even a diphthong that include [i] as its element is analyzed as heavy because it is lexical, and the mora is determined at the input level. However, a short vowel never appears in a stressed syllable. These properties are demonstrated in (78) and (79).

(78) Diphthongs

	O'odham		gloss	Spanish
g.	asáidi	$\sigma\acute{\sigma}_{\mu\mu}\sigma$	'oil'	< acéite
h.	alhúandi	$\sigma\acute{\sigma}_{\mu\mu}\sigma$	'elephant'	< elefánte

(79) Short Vowels

unattested

(no non-initial stressed on a syllable with a short vowel)

A summary of the occurrence of the vowels in stressed and unstressed positions in this type is found in (80). In a regular (or native) stress pattern, all vowel types can occur in stressed position. Short vowels and light diphthongs occur in unstressed position, while long vowels and heavy diphthongs do not occur in unstressed position. All but short vowels can occur in irregularly stressed position.

(80) Vowel Type and Syllable Positions

	regular stress	unstressed	irregular stress
Short V	√	√	_
Long V	√	_	√
Light Diphthong	√	√	√
Heavy Diphthong	√	_	√

Notice that both light and heavy diphthongs appear in the non-initial position. However, a light diphthong is also stressed in the non-initial position. I assume that it is inherently heavy due to the nature of stress marking on the borrowed words. This suggests that mora is indicated in input.

3.5.1 Lexical Specification

Prince (1990) states that there is a close relationship between stress and weight. The prominent lexical indication could be either from "stress" or "mora". For this reason, there are two ways to account for the non-native stress pattern. This leads to two different ways of thinking shown in (81).

(81) Stress or Mora

A syllable is stressed because it is heavy. $\sigma_{\mu\mu}$ -> $\acute{\sigma}_{\mu\mu}$

OR

A syllable is heavy because it is stressed. $\acute{\sigma}$ -> $\acute{\sigma}_{\mu\mu}$

Either a syllable is heavy because it is stressed, or a syllable is stressed because it is heavy. In the previous sections, I demonstrated that moras are predictable, so no specification of mora is contained in input, and that mora specification in the input is limited to lexically idiosyncratic forms. If we take the latter implication as a premise, the analysis of the non-native pattern stays proportional to the native patterns. In the following tableaux, diphthongs that are categorized as light in native vocabulary, are shown to be heavy in exceptionally stressed words due to the nature of lexical specification.

3.5.2 Class non-native: OT Analysis

In this section, OT analyses of non-native Class diphthongs are presented. In order to show an OT analysis of this class, I use the two words [ʔasáidi] 'oil' which has a diphthong and [kalsíida] 'sock' which has a long vowel.

(82) <u>Words Used</u>

a.	ʔasáidi	'oil'	(non-native diphthong)
b.	kalsíida	'sock'	(non-native long vowel)

As I mentioned previously, the relationship between stress and mora in Class L diphthongs can go in two ways. I assume lexical specification in input with mora; the lexical heaviness is indicated in the input representation with two moras as shown in (83).

(83) Input Form

$/\sigma\sigma_{\mu\mu}\sigma/$

There are also two facts regarding the corresponding relationship between stress and mora across input and output. First, a heavy syllable in the input is realized as heavy in the output as in (84).

(84) Output Form

Fact 1: heavy syllable in input --> also heavy in output

$/\sigma\sigma_{\mu\mu}\sigma/$ -> $[\sigma\sigma_{\mu\mu}\sigma]$

This input-output correspondence of heaviness can be accounted for by the use of MAX(μ) as shown in the previous section. Note that the syllable position must also correspond between input and output.

(85) MAX(μ):

The number of mora in a syllable in input must be maximized in output. (c.f. McCarthy 1995)

Secondly, a heavy syllable in output is always stressed, as in (86).

(86) Output Form

Fact 2: heavy syllable --> stressed

$/\sigma\sigma_{\mu\mu}\sigma/$ -> $[\sigma\acute{\sigma}_{\mu\mu}\sigma]$

This phenomenon can be accounted for by the Weight-to-Stress Principle defined by Prince (1990). Its basic assertion is that a heavy syllable is stressed. This is used in the OT analysis in the next sections that follow.

The list in (87) below shows the constraints that are used from the previous section. I provide an analysis of irregularly stressed diphthongs with these constraints and will modify them later by explaining the reason to do so.

(87) Constraints

MINWD: A word must be at least bimoraic.

MI: A vowel is moraic.

MAX(μ): mora in the input is maximized in the output.

FtFm: A foot must be even moraic trochee.

*Lapse: Avoid an unfooted syllable followed by a footed syllable.

PD: [i] in a diphthong 'lose weight' when adjacent to another vowel.

Faith(V): Vowel quality in input is faithful to that in output.

Parse-(σ): A syllable is footed.

First, the evaluation of a non-native word with a diphthong is considered using the word [ʔasáidi] which contains an irregularly stressed diphthong. MINWD and FAITH(V) are omitted, and the candidates in the tableaux below do not violate these constraints.

As shown in tableau (88) below, non-initially stressed vowels can be accounted for with the constraints and the ranking given earlier. Candidate (a) is the optimal output, but this is not the winning candidate in the tableau, suggesting that these constraints and their ranking must be modified later on. Candidate (b) is ruled out because it violates FTFM. Candidates (a), (c), (f) and (g) fail because they violate *LAPSE. Candidates (d) and (e) are tied at PD, but candidate (d) is selected because candidate (e) violates P-(s). The winning candidate (d) is incorrectly selected.

(88) ?asáidi **'oil': non-native, diphthong**

	/?asai$_{\mu\mu}$di/	FTFM	MAX(μ)	*LAPSE	PD	MI	P-(σ)
☞ a.	?a$_\mu$.(sái$_{\mu\mu}$.di$_\mu$)			*!	*		*
b.	(?a$_\mu$.sái$_{\mu\mu}$).di$_\mu$	*!			*		*
c.	?a$_\mu$.(sái$_\mu$.di$_\mu$)		*!	*		*	*
● d.	(?á$_\mu$.sai$_{\mu\mu}$)(dì$_\mu$)				*		
e.	(?á$_\mu$.sai$_{\mu\mu}$).di$_\mu$				*		*!
f.	?a.(sái$_{\mu\mu}$.di$_\mu$)			*!	*	*	*
g.	?a$_\mu$.(sái$_{\mu\mu}$).di$_\mu$			*!	*		**

The evaluation in (88) is incorrect. In order for the correct candidate (a) to be selected, I must introduce an additional constraint: WSP. This irregularly stressed syllable is always stressed. Prince (1990) presents a typological study about the relationship between weight and stress. The study has two directions. One is Weight-to-Stress Principle (WSP), stating that a syllable is stressed if heavy. Another is Stress-to-Weight Principle (SWP), stating that a syllable is heavy if stressed. In O'odham, WSP can be used in order to account for the evaluation of irregularly stressed syllables. SWP is not used because a light syllable can be stressed. If SWP is significant, no stressed light syllable can occur. WSP as an OT constraint is defined in (89):

(89) WEIGHT-TO-STRESSPRINCIPLE (WSP):

If a syllable is heavy, then it is stressed.

The tableau (90) that follows shows the correct evaluation with these two constraints. Both of them must be ranked higher than *LAPSE, since *LAPSE is not violated by the incorrectly winning candidate in tableau (88). In the new tableau (90), candidate (a) is the correctly winning candidate. Candidate (b) violates FTFM. Candidate (c) violates MAX(μ) for not maximizing the mora in output. Candidates (d) and (e) violate WSP because their heavy syllables are not stressed. Candidates (a), (f) and (g) violate *LAPSE, so they are in a tie at this point, and the competition is continued. Candidate (f) violates MI and fails. Candidate (g) violates P-(s) twice while candidate (a) violates it only once. Hence, candidate (a) is the correctly selected output.

(90) ʔasáidi **'oil': Class H, non-native, diphthong**

	/ʔasai$_{\mu\mu}$di/	FtFm	Max(μ)	WSP	*Lapse	MI	PD	P-(σ)
☞ a.	ʔa$_{\mu}$.(sái$_{\mu\mu}$.di$_{\mu}$)				*		*	*
b.	(ʔa$_{\mu}$.sái$_{\mu\mu}$).di$_{\mu}$	*!					*	*
c.	ʔa$_{\mu}$.(sái$_{\mu}$.di$_{\mu}$)		*!		*	*		*
d.	(ʔá$_{\mu}$.sai$_{\mu\mu}$)(dí$_{\mu}$)			*!			*	
e.	(ʔá$_{\mu}$.sai$_{\mu\mu}$).di$_{\mu}$			*!			*	*
f.	ʔa.(sái$_{\mu\mu}$.di$_{\mu}$)				*	*!	*	*
g.	ʔa$_{\mu}$.(saî$_{\mu\mu}$).di$_{\mu}$				*		*	**!

The modified constraints and ranking is shown in (91) below.

(91) Constraints and the Ranking:

MinWd, FtFm, Faith(V), Max-μ, WSP >> *Lapse >> PD >> MI >> Parse-σ

3.5.3 Class non-native: Long vowel

In this section, the evaluation of long vowel on non-initial stressed position is shown. For a word with a long vowel, an evaluation similar to the previous one is anticipated. It is shown in tableau (92). The winning candidate is (a). Candidate (b) violates FtFm for having the head on right. Candidate (c) violates Max(μ) because the second syllable does not maximize the number of mora as they are in input. Candidates (d) and (e) fail because of the WSP violation for not stressing the heavy syllable. Candidates (a), (f) and (g) violate *Lapse and the evaluation is tied at this point.

Candidate (f) violates MI for not having a mora in the first syllable. Candidate (g) violates P-(σ) twice while candidate (a) violates it only once. Hence, candidate (a) is selected, and this is the correct output.

(92) ***kalsíida*** **'sock': Class non-native, long vowel**

	/kalsi$_{\mu\mu}$da/	FTFM	MAX(μ)	WSP	*LAPSE	PD	MI	P(σ)
☞ a.	ka$_\mu$l.(sí$_{\mu\mu}$.da$_\mu$)				*			*
b.	(ka$_\mu$lsí$_{\mu\mu}$).da$_\mu$	*!						*
c.	ka$_\mu$l.(sí$_\mu$.da$_\mu$)		*!		*			*
d.	(ká$_\mu$l.si$_{\mu\mu}$).(da$_\mu$)			*!				
e.	(ká$_\mu$l.si$_{\mu\mu}$).da$_\mu$			*!				*
f.	kal.(sí$_{\mu\mu}$.da$_\mu$)				*		*!	
g.	ka$_\mu$l.(sí$_{\mu\mu}$).da$_\mu$				*			**!

The ranking in (93) is the same as before:

(93) Constraints and Ranking:

MINWD, FTFM, FAITH(V), MAX-μ, WSP >> *LAPSE >> PD >> MI >> PARSE-σ

3.5.4 Secondary Stress

Fitzgerald (1997, 2001) shows analysis of secondary stress in O'odham. O'odham carries secondary stress when there are four syllables in a word. But a trisyllabic word can also have secondary stress when the word is polymorphemic. She proposes the MPS constraint, which enhances the relationship between stress and morpheme. This relationship is revealed by the stress pattern that I already mentioned; a trisyllable word carries secondary stress when polymorphemic. A simple example of this is represented in the contrast between *músigo* 'musician' and *múmsigò* 'musicians', as (94) illustrates.

(94) Secondary Stress

a.	músigo	monomorphemic
b.	mú-msigò	polymorphemic

The prior analysis I conducted does not contain any secondary stress. It must be shown that the constraints and the ranking presented above are also compatible with secondary stress. I use the three words in (95) as examples.

(95) Word Used for Analysis of Secondary Stress[1]

a.	páko?òla	'clown dancer.'	monomorphemic
b.	pá-padò-ga	'duck owning pl.'	polymorphemic
c.	páan-čud-dàm	'bread maker'	polymorphemic with Class H vowel

[1] Irregular words with more than three syllables are not attested, and evidence of stress assignment for such words does not exist. No fieldwork in this area of inquiring has been done.

First, let us examine the analysis of *póko?òla* 'clown dancer.' MINWD, and FAITH(V) are omitted. In tableau (96), candidate (a) is the correct output. Candidate (b) violates FTFM, and candidates (c) and (d) violate *LAPSE. Candidate (e) is ruled out for violating P-(σ).

(96) páko?òla: 'clown dancer' Class L, short vowel

	/pako?ola/	FTFM MAX(μ)	WSP	*LAP	PD	MI	P(σ)
☞ a.	(pá$_μ$.ko$_μ$)(?ò$_μ$la$_μ$)						
b.	(pá$_μ$.ko$_μ$)(?o$_μ$là$_μ$)	*!					
c.	pa$_μ$.(kó$_μ$?o$_μ$)la$_μ$			*!			**
d.	pa$_μ$.ko$_μ$(?ò$_μ$la$_μ$)			*!			**
e.	(pá$_μ$.ko$_μ$)?o$_μ$la$_μ$						**

The next tableau (98) shows the evaluation of *papadoga*. Candidate (a) is the winner. Candidate (b) violates FTFM, for the second foot is not left headed. Candidate (c) violates MSP, which is claimed by Fitzgerald (1997). This is mentioned in an earlier section, but I restate this constraint in (97):

(97) MSP:

For every morpheme, there exists some stressed syllable that falls in the domain of that morpheme.

Therefore, the correct candidate (a) is selected.

(98) pápadòga: **'duck owning' Class L, short vowel**

	/pa-pado-ga/	FTFM MAX(μ)	WSP	*LAP	MSP	PD	MI	P(σ)
☞ a.	(pá$_\mu$-pa$_\mu$)(dò$_\mu$-ga$_\mu$)							
b.	(pá$_\mu$-pa$_\mu$)(do$_\mu$-gà$_\mu$)	*!						
c.	(pá$_\mu$)-pa$_\mu$(dó$_\mu$-ga$_\mu$)			*!				*
d.	(pá$_\mu$-pa$_\mu$)do$_\mu$ga$_\mu$				**!			**

The last tableau (99) shows the evaluation of the word *paančuddam*. Candidate (a) is the correct output. Candidate (b) violates FTFM, for having a foot that is not left headed. Candidate (c) fails because it violates WSP for not stressing the heavy syllable. Candidate (d) also fails because it violates MSP. The correct candidate (a) wins.

(99) ***paan-čud-dam*****: 'bread-causative-agent: baker' Class H, short vowel**

	/paan-čud-dam/	FTFM MAX(μ)	WSP	*LAP	MSP	PD	MI	P-σ
☞ a.	(pá$_\mu$a$_\mu$n-ču$_\mu$d)(dà$_\mu$m)				*			
b.	(paa$_\mu$n-čú$_\mu$d)da$_\mu$m	*!			**		*	*
c.	pa$_\mu$a$_\mu$n-ču$_\mu$d(dà$_\mu$m)		*!	*	**			**
d.	(pá$_\mu$a$_\mu$n-ču$_\mu$d)da$_\mu$m				**!			*

The last two tableaux (100) and (191) show that the analysis given above still works for words that have single consonant reduplication. Tableau (100) shows the evaluation of *musigo* 'musician', which is a monomorphemic disyllable. The correct candidate is selected under the same constraints and the ranking as previously shown. The crucial point in the evaluation (199) is that *LAPSE dominates FTBIN (Fitzgerald 1997).

(100) *musigo*: 'musician', monomorphemic, Class L, Short Vowel

	/musigo/	FTFM MAX(μ)	WSP	*LAP	MSP	FTBIN	PD	MI	P(σ)
☞ a.	(mú$_\mu$si$_\mu$)go$_\mu$								*
b.	mu$_\mu$(sí$_\mu$go$_\mu$)			*!					
c.	(mú$_\mu$si$_\mu$)(gò$_\mu$)					*!			

The tableau in (101) shows the evaluation of the bimorphemic disyllable, *mumsigo* 'musicians'. The correct candidate (a) is selected although it violates FTBIN. The other candidates (b) and (c) are ruled out by the higher ranked constraints.

(101) *mumsigo*: 'musicians', bimorphemic: Class L, Short Vowel

	/mumsigo/	FTFM *CLASH	WSP	*LAP	MSP	FTBIN	PD	MI	P(σ)
☞ a.	(múmsi)(ḡo)					*			
b.	(múm)(sǐgo)	*!				*			
c.	mum(sǐgo)			*!	*				*

Therefore, my analysis still derives a correct evaluation of words with secondary stress in O'odham.

The final constraint ranking is shown in (102) below.

(102) Constraint Ranking

{ MinWd, FtFm, *Clash, Faith(F), Max(μ), WSP } >> *Laps >> MSP >> { FtBin, PD } >> MI >> Parse-σ

3.6 Conclusion

In this chapter, both data description and OT analysis of diphthongs in Tohono O'odham have been presented. Diphthongs occur in natural languages. They are usually categorized into falling and rising diphthongs by sonority. However, Tohono O'odham diphthongs are categorized into two classes by the weight: Class L and Class H. Class L diphthongs are light and Class H diphthongs are heavy. These two classes apply to regular vowels. Short vowels belong to Class L, and long vowels to in Class H.

The chapter contributes to phonological theory. First, I proposed a constraint that forces a vowel to be moraic: MoraIndispensability (MI). This constraint determines the moraicity in output with no mora indications needed in input. Heavy vowels are considered to be made up of two single vowels, hence bimoraic. However, any diphthongs will be bimoraic with this concept. A light diphthong turns out as bimoraic due to MI, although they are monomoraic. In order to account for the weight of light diphthongs, POSITIONALDIET (PD) was introduced. O'odham diphthongs are light when they include [i] as an element of their diphthongs. PD forces this [i] to be non-moraic when it is an element of a diphthong. This is strictly language specific, and further research must be done on this idea.

Irregularly stressed vowels are always bimoraic. The weight of vowels in irregularly stressed words must be learned. That is, it has to be indicated in input. On the other hand, the weight of regularly stressed vowels is not indicated in input. Words with secondary stress are still correctly accounted for. There is no secondary exceptional stress attested.

In this chapter, the weight of two vowel classes is described and accounted for. The two different classes for diphthongs are foreign to English phonology. This phonological difference causes a difficulty for learners of Tohono O'odham whose first language is English. This particular aspect of second language learning/acquisition is presented in Chapter 4.

CHAPTER 4: SOUND PRODUCTION OF DIPHTHONGS IN L1 AND L2

4.1 Introduction

In the previous chapter, I outlined the phonological distribution of O'odham diphthongs and analyzed it within the framework of OT. The main innovation regarding the O'odham diphthongs was their categorization into two groups based on weight. This type of classification is still new and one may wonder how plausible it is. In this chapter, I attempt to show some support for claims made in Chapter 3 using acoustic and experimental studies.

This chapter focuses on two phenomena: i) native speaker production and ii) learner production of Tohono O'odham diphthongs. I obtained sample data from a native speaker of Tohono O'odham in order to map the durational difference between the production of light diphthongs and heavy diphthongs in natural speech. I hypothesize that learners of Tohono O'odham do not distinguish these two categories, but are instead influenced by transfer from L1 (English) to L2 (Tohono O'odham). Investigating the acoustic facts with experiments like this represents a significant contribution to applied linguistics. The results of a study such as this can be useful for language education in the case of both native and non-native language learners. As mentioned in Chapter 1, transfer effect is assumed in my experiment. Transfer is the main factor for learners' production when they map linguistics factors from their L1 onto an L2.

First, I provide a brief review of Tohono O'odham diphthongs. Then I present the hypotheses for the experiment. I also present data, describe the method of my experiment, and the list the results. Finally, I offer a discussion of the ramifications of my results including pedagogical implications. This chapter is unique because it gives innovative examples of Tohono O'odham linguistic study involving second language acquisition. It also shows the importance of the literature on Tohono O'odham linguistics as an important step to language education and language maintenance.

4.2 Review

In this section, I briefly summarize the description of O'odham diphthongs as a reminder before moving onto the hypotheses. There are 14 existing diphthongs in O'odham, and these diphthongs fall into two categories: light and heavy. This classification is separate from the categories that differentiate rising vs. falling diphthongs. Light diphthongs contain the high front vowel [i] in their elements, and heavy diphthongs do not.

(1) **Example**

Light		Heavy	
haiwañ	'cow'	doag	'mountain'
čɨggia	'fight'	čɨoǰ	'boy'

The distribution of these two types of diphthongs is unique with regards to stress assignment. Heavy diphthongs always appear in the stressed position, and light diphthongs can appear in both stressed and non-stressed positions.

As mentioned in Chapter 3, based on the distribution, the following weight difference between the two types of diphthongs is theoretically made.

(2) Generalization of Moraic System:

A heavy diphthong is always bimoraic and a light diphthong is monomoraic when unstressed.

The above statement is illustrated in (3). The symbol σ indicates a syllable, and the symbol μ indicated a mora.

(3) Moras of Light and Heavy diphthongs

a. Light	b. Heavy
σ	σ
|	Λ
μ	μμ
|	| |
VV	VV

4.3 Hypotheses

Of interest here is the manner in which this generalization appears acoustically. There may be some acoustic realization regarding these two categories of diphthongs among users of O'odham. However, even if a native speaker's pronunciation captures the distinction between the two, learners of Tohono O'odham may have difficulty producing the distinction of the two groups. In this section, the three hypotheses that were tested are described.[1]

[1] Because I provide one native speaker's acoustic data, the findings cannot be generalized statistically to all O'odham. The data can be suggestive, but not conclusive, of a pattern for all speakers. Even so, the inclusion of data from a native speaker of Tohono O'odham represents a significant contribution to the literature, as no such data has been provided before.

4.3.1 Hypothesis I

Strictly following the theoretical analysis shown in Chapter 3, a monomoraic segment must be shorter than a bimoraic segment. Light diphthongs are monomoraic, and heavy diphthongs are bimoraic. Therefore, I expect to find a difference between the duration of heavy and light diphthongs in a native speaker's speech.

Light diphthongs appear as monomoraic in second syllable position which is unstressed by default. No heavy diphthongs appear in unstressed second position. When they appear in the second position, they will receive stress irregularly. From this fact, if these two groups of diphthongs are in the second unstressed syllable position, a native speaker would make a distinction in pronunciation with regards to stress. Light diphthongs are short, similar to regular short vowels. On the other hand, heavy diphthongs are long, and therefore they should be enforcing the syllable to be more like stressed, similar to irregularly stressed syllables. The hypothesis thus far is summarized in (4).

(4) Hypothesis on Native Speaker's Production

In a native speaker's speech production, light diphthongs and heavy diphthongs in unstressed position are pronounced with different duration. In other words, heavy diphthongs are longer.

4.3.2 Hypothesis II

When both light and heavy diphthongs are in the first syllable position (stressed by default), both appear as bimoraic as shown in Chapter 3. This leads me to hypothesize further that a native speaker will make no significant difference between light and heavy diphthongs in duration. Light diphthongs are bimoraic in stressed position as opposed to unstressed position. Heavy diphthongs are always bimoraic. Therefore, I expect to see no difference in duration between light and heavy diphthongs.

(5) **Hypothesis on a Native Speaker's Production 2**

A native speaker does not produce significant difference between light and heavy diphthongs when they are pronounced in the first syllable position.

4.3.3 Hypothesis HI

Tohono O'odham learners are not being introduced to these two different types of diphthong groups as a part of their language training. Diphthongs in Tohono O'odham have different characteristics from English as shown in Chapter 3. Currently in Tohono O'odham language education, learners have no grammatical or descriptive explanation of such information. Their first language (L1) is English, which exhibits a different pattern of diphthongs. For example, there is no short diphthong.[2] According to the *transfer effect* (Chapter 1), any diphthong is assumed to be pronounced by learners as heavy, and not light because of the patterns they have internalized from English. Therefore, we should not see any diphthong differentiation within the learners' speech.

(6) **Hypothesis of Learners' Production**

No difference between the two groups of light and heavy diphthongs are seen in the learners' production.

4.4 Method

I tested the hypotheses above with an experiment involving a native speaker and eight learners of Tohono O'odham. I used disyllables for collecting the raw data. It was necessary to use disyllables and not monosyllables, since O'odham stress goes on the first syllable and second syllables are unstressed by default. Two syllable words were needed in order to make duration comparisons between stressed and unstressed positions. It is impossible to make such comparison with monosyllables because all Tohono O'odham monosyllables are considered stressed. Also I did not use words consisting of three or more syllables because Tohono O'odham involves secondary stress in trisyllabic words when they are polymorphemic. In order to avoid such complications, I limited my data to disyllables. A word with two syllables will have enough contrast between stressed and unstressed syllables to produce the required data.

I measured the duration of the vowel pronunciations. Raw data, which is shown in Appendix A, are converted by using the ratio between the duration of the first and second syllables. Everybody has different rate of speech, and even the same speaker may produce the same word at a different speed during different utterances. The use of ratio between the first syllable and the second syllable can correct for this inconsistency of pronunciation speed.

The example measurement of the conversion is described in (7). The following table shows the sample data of vowel length measured from the native speaker's production. The syllable form is CVCVV (disyllable with a short vowel in the first syllable position and a light diphthong in the second syllable position).

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[2] Instead, English has vowel reduction from diphthong to schwa in an unstressed position. Tohono

(7) CVCVV

		A	B	C
humie	115	.14	.13	1.1

Column A shows the duration of the first syllable in a sample word, and column B shows the duration of the second syllable. Column C shows the ratio of the two vowels in a word. The ratio can provide the relative length such as how long the first vowel is compared to the second vowel. The inconsistency of the pronunciation speed of speakers is avoided. The calculation of the ratio is shown in (8).

(8) Ratio Calculation

A. Duration of the vowel in the first syllable (CVCVV) is .14 msc

B. Duration of the vowel in the second syllable (CVCVV) is .13 msc

The ratio of the two is determined by the fraction.

Ratio C = A divided by B (A/B = C)

.14/.13 = 1.1

Therefore, the ratio value between A and B is 1.1 msc.

In the case of the sample word measurement, the duration of the diphthong is about the same as the duration of a short vowel. When the number of the ratio is smaller than one, it shows that the duration of the vowel in the second syllable is longer than the vowel in

O'odham retains diphthong quality even in an unstressed position.

the first syllable. On the other hand, when the ratio is greater than one, the duration of the vowel in the first syllable is longer than that of second syllable as shown in (9).

(9) Ratio and Gradient

n<1: the second vowel is longer than the first vowel (V1<V2)

n>1: the first vowel is longer than the second vowel (V1>V2)

n=1: the length of the two vowels is the same (V1=V2)

4.4.1 Subjects

Subjects are one native Tohono O'odham speaker and eight learners. The native speaker is literate[3] in Tohono O'odham, and learned English as his second language at the age of seven in school.

All learners' first language is English, and they were all taking first or second semester Tohono O'odham at the University of Arizona at the time of the experiment. Some of them were O'odham descendants who have experience in hearing O'odham speech, but none were speaking it as their first language. My experiment does not distinguish them based on their cultural background because I considered their knowledge in Tohono O'odham to be the same as that of non-O'odham descendants regarding learner production.[4]

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[3] Tohono O'odham writing system has been used for about 25 years. Only a very small portion of the population native speakers can write and read in Tohono O'odham. (p.c. Zepeda)

[4] However, their perception is definitely different. Those who were exposed to the Tohono O'odham culture through their family demonstrated better listening comprehension in O'odham.

4.4.2 Subjects' Task

Each session is 20 minute involved one individual subject. I prepared nonsense O'odham words written on cards, and subjects were randomly shown the words one by one. The native speaker agreed to pronounce the words as if they were O'odham words. On the other hand, the learners were told that the words were O'odham words that they might not have learned yet in the class in order to motivate them to pronounce the words as O'odham like as possible. They were informed about the purpose of the experiment, including the use of nonsense words, at the end of the session. The whole session was tape-recorded, and the recorded sessions were digitized via SoundEdit16. Each word was filed separately. The vowel length was measured using the Praat program, which shows acoustic analyses for multi-purposes. Among them, I used the duration measurement program in order to collect numerical data on O'odham diphthongs.

4.4.3 Data

In this section, the data used are described. Syllable types are described.

4.4.3.1 Syllable Type

As I mentioned earlier, I used disyllables in order to get ratios of two syllables per word. The syllable patterns used for the experiment were cv́cvv and cv́vcv. VV represents a diphthong, so the first type is a disyllable with either a light or heavy diphthong in second position which is unstressed by default, and the second type is with a diphthong in the first position which is stressed by default.

(10) Syllable Types

a. CVCVV: disyllable with diphthong in the second (unstressed) position

b. CVVCV: disyllable with diphthong in the first (stressed) position

4.4.3.2 Words

The list of nonsense words used is given in Appendix A. All words include diphthongs (CVV). I used all 14 existing O'odham diphthongs for these three syllable types.

There are a few motivations for the decision to use nonsense words. First, there are only a few words in O'odham that contain a certain diphthongs. For example, the diphthong [au] appears in only one word, which is *naupait* 'to make wine'. In order to test with the three different syllable types, CV, CVCVV, and CVVCV, word creation was necessary for those syllable types that do not have actual words with a diphthong. Second, when a word is created only for the purpose of the experiment, the word created will have no reference, hence becomes nonsense words. This method is assumed to eliminate any association of the words to meanings, which might affect subjects' production subconsciously.

4.5 Results

The result of the experiment is shown in this section. First, the descriptive statistics are shown. Then a statistical analysis is presented.

The descriptive statistics (see Table 1) indicate that the data supports all three hypotheses. In Table 1, the numbers outside of the parentheses are mean ratios, and the numbers in parentheses are standard deviations. The first hypothesis is that a native speaker will make a distinction in duration between the two diphthong groups in unstressed position. The mean ratio of light diphthongs in the second syllable of a disyllabic word in the Native speaker's production is .93 milliseconds, while heavy diphthong in the same position is .59 milliseconds. This means that light diphthongs in the second syllable of a disyllabic word were pronounced by this speaker on average .34 milliseconds faster than were heavy diphthongs in the same environment. In both of these conditions, the standard deviation values of .14 and .22 are smaller than the average durational difference between the two classes of diphthongs. This means that the variability in the duration of light diphthongs (which is represented by the standard deviation for that condition, or .14 milliseconds) as they were produced over several different tokens by the native speaker of O'odham is much less than the average difference between the light diphthongs and the heavy diphthongs (.34 milliseconds) in the second position of disyllabic words. Similarly, the variability in duration of heavy diphthongs in this position across multiple tokens (.22 milliseconds) is less than the average difference between light diphthongs and heavy diphthongs in this position. Hence, there is a clear descriptive difference between the two types of diphthongs as they are produced by the native speaker. In subsequent sections, I will show that this difference is statistically significant as well.

The second hypothesis stated that light and heavy diphthongs in stressed position (the first syllable of a disyllabic word) are not distinguished in the native speaker's production. This hypothesis is also supported by a descriptive review of the results, as follows.

The mean ratio of light diphthongs in stressed position by the native speaker is 1.56 milliseconds, and heavy diphthongs is 1.36 milliseconds. Both diphthongs are a much longer than regular short vowels. There is a .2 millisecond difference, on average, between the light and heavy diphthongs in this native speaker's production, making it appear that the light diphthongs are still slightly shorter in duration than the heavy diphthongs in this environment. However, the standard deviation values for this condition show that the .2 millisecond average difference between heavy and light diphthongs is actually less than the durational variability in the speaker's production of different tokens of heavy diphthongs (standard deviation = .3 milliseconds), and also less than the durational variability in the speaker's production of different tokens of light diphthongs (standard deviation = .25 milliseconds). Therefore, the apparent .2 millisecond difference between heavy and light diphthongs in this condition is illusory – there is more variability within this speaker's production of heavy diphthongs than there is between heavy and light diphthongs in this position. Similarly, there is more variability within this speaker's production of light diphthongs than there is in his production of light diphthongs. The data conclusively show that there is no meaningful difference in duration between the production of heavy and light diphthongs in stressed position for this speaker, and Hypothesis II is therefore supported.

The third hypothesis was that learners would not make any distinction between the duration of heavy and light diphthongs in either stressed or unstressed position. This hypothesis is supported by a descriptive review of the results, as follows.

We begin with a case analogous to that presented for Hypothesis I. When learners produce heavy and light diphthongs in the second syllable of a disyllabic word (that is, in unstressed position), we find the mean ratio of light diphthongs to be .47 milliseconds, and the mean ratio of heavy diphthongs to be .41 millisecond. This shows that diphthongs of both groups are produced with longer than regular short vowels.

However, the .05 millisecond average difference between the ratios for heavy and light diphthongs in this environment is much smaller (in absolute terms) than the .34 millisecond average difference found in the production of the native speaker for diphthongs in the same environment. Furthermore, the .05 difference found between heavy and light diphthongs in unstressed position as produced by learners is smaller than the variability in their production of heavy diphthongs (standard deviation = .07 milliseconds). The variance between the duration of heavy and light diphthongs in this environment is only slightly greater than the variance within these speaker's production of light diphthongs (standard deviation = .04 milliseconds).

What can be concluded from these data is this: Language learners produce both heavy and light diphthongs in unstressed syllables extremely consistently. The average durational differences between heavy and light diphthongs (.06 milliseconds) as well as the variability within the duration of heavy diphthongs across multiple tokens (.07 milliseconds), and of light diphthongs across multiple tokens (.04 milliseconds) is much smaller than the durational differences found in the production of the native speaker. In the native speaker's production, the average difference between heavy and light diphthongs was .34 milliseconds – and the standard deviation for heavy diphthong production was .14 milliseconds, for light diphthong production it was 0.22 milliseconds. The native speakers' durational differences are at least twice as large as are those of the language learners.

Furthermore, because the average difference between heavy and light diphthong production for language learners is less than the standard deviation for heavy syllable production, we can conclude that there is no meaningful durational difference being produced by language learners in the production of heavy and light diphthongs in unstressed position.

For diphthong in stressed position, the same generalizations hold. There is a .03 milliseconds average difference in durational ratio between learners' production of light and heavy diphthongs. This is slightly less than the difference for learners' production of light and heavy diphthongs in unstressed syllables, and much less than the differences found for the native speaker's production of diphthongs in stressed syllables. The very small standard deviations (standard deviation = .02 milliseconds) for learners' production of heavy and light diphthongs in stressed syllables indicates that learners are extremely consistent in their productions of diphthongs, regardless of whether they are heavy or light.

In this case, the average difference in duration is slightly greater (.01 millisecond) than the standard deviation for either syllable type. It is clear that this .01 millisecond difference is negligible compared to the native speaker's .34 millisecond distinction in the same position, and Hypothesis III is fully supported by the data.

Table 1 (Descriptive Statistics)

		Native Speaker[a]	Learners[b]
		M (SD)	M (SD)
Unstressed	Light	.93 (.14)	.47 (.04)
	Heavy	.59 (.22)	.41 (.07)
Stressed	Light	1.56 (.25)	1.82 (.2)
	Heavy	1.36 (.3)	1.85 (.2)

[a]Native: 8 words produced by 1 subject

[b]Learners: 8 words produced 8 subjects

The first hypothesis predicted that a native speaker will make significant differentiation in the production of light and heavy diphthongs in second syllable position, which is unstressed by default. In the above discussion, I showed that there is a clear durational difference between these syllables, and that the difference goes in the hypothesized direction. However, confirmation of this hypothesis is also subject to statistical validation. To test for the hypothesized durational difference, a Mann-Whitney rank-order correlation was computed. Because only one native speaker participated in the experiment, and because the number of sample pronunciations of light and heavy diphthongs are not the same for this speaker, a non-parametric, rank-order statistic was required. The Mann-Whitney correlation was determined to be the best test for the data, given these limitations. The result of the analysis revealed that the difference between light and heavy diphthongs in unstressed position is significant within the native speaker's production ($U=4.00$, $P < .05$). Therefore, the distinction in duration between the two types of diphthongs is a significant one, and Hypothesis I is further supported.

The second hypothesis suggested that a native speaker would not make a significant distinction in duration between light and heavy diphthongs in stressed position. As we would expect, a statistical analysis (again using the Mann-Whitney correlation, for the reasons described above) shows no significant difference in the duration of this speaker's production of light and heavy diphthongs. ($U=13$, n.s.). Note that this finding is actually irrelevant to the confirmation of Hypothesis II, as that hypothesis predicted no difference between the two types of diphthongs – it did not merely predict the absence of a statistically significant difference between them. The presentation of the results in the discussion of Hypothesis II above shows that there is a true lack of difference in the duration of light versus heavy diphthongs in unstressed position in the speech of the Native Speaker.

The third hypothesis predicted that learners would make no distinction between the two groups in both stressed and unstressed positions. To show that the small durational differences found in the production of light and heavy diphthongs in either position by non-native speakers was not significant, a T-test was computed. The T-test is a more sensitive test than is the Mann-Whitney correlation, it is an interval-level parametric test, and it's use is justified by the fact that there were 8 participants in the non-native speaker condition of the experiment. The result reveals that the durational differences found in the speech of learners between light and heavy diphthongs in unstressed position was not significant ($T = 1.58$, n.s.), nor was the difference between the duration of heavy and light diphthongs stressed position as they were produced by learners significant (T = -.38, n.s.). Again, this finding is unsurprising given the discussion above. Hypothesis III did not merely predict the lack of a statistically significant difference in these two cases – it predicted that there would be no difference at all. The data show that there is effectively no difference in the duration of light and heavy diphthongs in the speech of language learners, regardless of the stress environment in which the diphthongs appear, and Hypothesis III is confirmed.

4.6 Discussion

In this section discussion, based on the results shown in the previous section is presented. First, a description of the predictions that are supported is discussed. Second, the relationship between the experiment and theory is discussed. Then learners' production regarding the error they made is discussed. Finally, the pedagogical implication is provided.

4.6.1 Native Speaker's Production: Diphthongs in Unstressed Position

The relationship between the syllables in disyllables with diphthongs in second syllable position is illustrated in (11). The duration of the two syllables in a CVCVV shape word with a light diphthong in second position (a) is about the same. The duration of the two syllables in a word of shape CVCVV with a heavy diphthong, on the other hand, is different - the second syllable is heavier (longer in duration) than is the first syllable.

(11) Native Speaker: Syllable Weight Relationship in CVCVV

a.	Light	b.	Heavy
	$\sigma 1 \cong \sigma 2$		$\sigma 1 < \sigma 2$

The interesting point is that there are no native O'odham words that have heavy diphthongs in unstressed position, but the data included heavy diphthongs in second syllable position which is considered unstressed by default. However, as the results show, the Native speaker did distinguish the two groups. That is, the speaker subconsciously treated these second syllables with a diphthong as if they were irregular, making them bimoraic. They are possibly being treated as stressed syllables just like in the borrowed words with exceptional stress.

4.6.2 Native Speaker's Production: Diphthongs in Stressed Position

As shown in the results, no difference is seen between the two groups of diphthongs in the case of CVVCV. In both groups, the stressed diphthongs are always longer than unstressed short vowels. This is illustrated in (12) below.

(12) Native Speaker: Syllable Weight Relationship in CVVCV

a.	Light	b.	Heavy
	$\sigma 1 > \sigma 2$		$\sigma 1 > \sigma 2$

Therefore, there is no distinction between light and heavy diphthongs when they are in the first syllable position.

4.6.3 Summary of Native Speaker's Production

From the native speaker's production, I conclude that the characteristics of light and heavy diphthongs in disyllables are as follows.

(13) The Native Speakers' Production

CV́VCV:	Following the rule of O'odham phonology, primary stress is on the first syllable, so a diphthong is stressed, and its duration is longer than the second syllable vowel. No particular distinction of light and heavy is necessary.[5]
CV́CVV(L):	When light diphthong occurs in the second position, its duration is short. The duration of the vowels in this disyllable type is about the same.
CVCV́V(H):	When heavy diphthong is in the second position, its duration is longer than the first vowel.

There was only one native O'odham-speaking subject who contributed to this experiment, and the speaker's pronunciation supports my research.

4.6.4 Support for Theoretical Analysis

I have mentioned in Chapter 3 that the moraic structure of light diphthongs and heavy diphthongs in words of shape CVVCV were different from each other. Light diphthongs were monomoraic and heavy diphthongs were bimoraic. However, as shown,

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[5] O'odham phonemically distinguishes long vs. short vowels. However, whether the short vowel in the first syllable position becomes longer has not been tested. Yet, there seems to be a vowel lengthening due to the stress assignment, and this lengthening is quite audible. (Chapter 5)

in the case of CVVCV, since the first syllable is longer than the second syllable without any distinction between the two diphthong types, the acoustic realization is long for diphthongs in general. The light diphthong is light only when it is in an unstressed position. Therefore, it supports my analysis that a candidate like CV́V(L)CV vacuously satisfies PD, which is repeated in (14) below.

(14) **POSITIONALDIET (PD):**

Among two vowels in a diphthong, a high front vowel [i] carries no weight when the other element is non-identical.

In tableau (15), the light diphthong is found to be bimoraic in stressed position. This tableau also appeared in Chapter 3. Candidates (a) and (b) resulted in almost identical outputs, except their moraic structure differed from each other. Candidate (b) failed because it violated MI, and the other candidate (a) won because it did not violate PD. The light diphthong is in the st*ressed* **pos**ition, SO IT IS NOT SUBJECT TO THIS CONSTRAINT, RATHER, VACUOUSLY SATISFIES IT.

(15) HA@IWAÑ 'COW'

	/HAIWAÑ/	MW	FTFM	FAITH(V)	*LAPSE	PD	MI
☞ a.	(há$_\mu$i$_\mu$.wa$_\mu$ñ)						
b.	(há$_\mu$i.wa$_\mu$ñ)						*!

Therefore, the result in this experiment also supports my theoretical analysis given in Chapter 3.

4.6.5 Learners' Production: Unstressed Position

Diphthongs in unstressed position were what the native speaker distinguished in the duration. The native speaker's light diphthong was short, while the heavy diphthong was long. On the other hand, learners' production of diphthongs in unstressed position does not make any distinction. Both diphthong types were longer than regular vowels. The relationship between the first syllable and second syllable in their production is illustrated in (16).

(16) Learners: Syllable Weight Relationship in CVCVV

Light	Heavy
$\sigma 1 < \sigma 2$	$\sigma 1 < \sigma 2$

The learner group's first language is English. Since light diphthongs are "foreign" to them, they likely cannot perceive monomoraic diphthongs and therefore pronounce them as regular bimoraic diphthongs due to transfer effect from the L1.

4.6.6 Learners' Production: Stressed Position

The native speaker did not make any distinction between light and heavy groups regarding diphthongs in stressed positions. Learners also did not make any distinction, since both diphthong types are treated as bimoraic.

(17) Learners: Syllable Weight Relationship in CVVCV

Light	Heavy
$\sigma 1 > \sigma 2$	$\sigma 1 > \sigma 2$

Differences between the duration of light and heavy diphthongs within the two groups (native speaker/learners) is statistically supported. However, the difference between the native speaker's and learners' productions was not statistically examined. In order to pursue this interest, a larger number of subjects is necessary.

The table shown in (18) is a summary of the relationship between the syllable weight of first and second syllables from the experiment.

(18) Summary Table

	Native		Learners	
Syllable Type	Light	Heavy	Light	Heavy
CVCVV	$\sigma 1 \cong \sigma 2$	$\sigma 1 < \sigma 2$	$\sigma 1 < \sigma 2$	$\sigma 1 < \sigma 2$
CVVCV	$\sigma 1 > \sigma 2$	$\sigma 1 > \sigma 2$	$\sigma 1 > \sigma 2$	$\sigma 1 > \sigma 2$

4.6.7 Pedagogical Implication

Most native speakers of Tohono O'odham are grandparental generations (see Chapter 1). The number of children who are learning the language as their mother tongue is decreasing. Elementary schools on the reservations use English as the means of instruction. Tohono O'odham speaking children will learn English during the school years. Since Tohono O'odham is not used in school as means of instruction, non-

Tohono O'odham speaking children, then, have no environment in which to acquire their traditional language. However, some strategies toward language maintenance are used in school (Shavez p.c.).

Children in O'odham language classes are not taught to communicate in O'odham. Rather, they learn vocabulary and phrases through the study of tradition, such as native plants, animals and seasonal events. It is a culture class rather than a language class. The language part of the class consists of introducing names and phrases in Tohono O'odham. That is, children who do not speak Tohono O'odham at home are unlikely to receive an education that could bring them up a native or near-native fluency level. Such courses are useful for only those who already speak O'odham. In order to help children who do not speak it natively, it is necessary to reconsider the curriculum. However, the problem then shifts to the experience and knowledge that O'odham language teachers possess.

4.6.7.1 Linguistics and Language Teaching

As an ideal language teacher qualification, I suggest two major factors regarding the development of an effective language curriculum. First, a teacher must be a native speaker of the target language. A teacher must be able to give examples to students, and students need to be exposed to the language. According to this idea, the students in the O'odham language class must be taught by a native O'odham speaker. Second, a teacher must be trained to be a language educator. This is not satisfied just by being a native speaker of the target language. Similar to the fact that English speaking ESL teachers are trained in pedagogy, language teachers must obtain techniques to teach students a second language. ESL teachers obtain skills to help students to be fluent and to be able to use

English in everyday life. However, teaching O'odham may imply more of teaching to "be" O'odham, unlike teaching English to non-native speakers. The Tohono O'odham language is endangered and teachers could be expected to help teach the language in order to maintain the language as a part of the whole O'odham culture. It sounds more serious than ESL because ESL does not aim for language maintenance of English. Of course, there is no need for language maintenance efforts for English at this moment. In sum, both being a native speaker of O'odham and being an effective educator are the factors I would like to suggest for O'odham language education.

Tohono O'odham teachers on the reservations satisfy the first factor. But they may not always be trained as educators. Since there is always immediate need for native speakers who can teach languages yet there is no time for them to receive education, a time conflict results if they want to pursue the professional language teaching skills.

The American Indian Language development Institute (AILDI) offered at the University of Arizona gives teachers the opportunity to pursue such an interest. This institute is designed for people who are needed for teaching[6], but have little time to pursue education. It provides intensive courses with respect to language curriculum, linguistics and other related fields every year (McCarty 1993). However, since it is an intensive one month institute, the contents that the participants can obtain are only two courses, while one can obtain 8 to 10 for undergraduate and 4 to 6 courses for graduate program in a year if they study in a more traditional program. In other words, the process of rigorous teacher development can be slow.

Moreover, there is another technical problem behind teacher education. The training for teachers of endangered languages starts with basic descriptive linguistic components. This is a very common and necessary process when working with such languages because their grammar is often still being discovered, while teachers of English are usually able to make use of hundreds of published English grammar works when developing a language curriculum. In other words, linguists have already done work on finding out the grammar of English and teachers are using it for their own classes. However, Tohono O'odham teachers do not have many grammar books to work from. They often have to start from scratch and it takes enormous amount of time. Linguists should be available in order to provide the information that teachers can make use of to develop curriculum.

In the following sections, I provide a few suggestions, as a linguist, as to how teachers can make use of linguistic literature using my analysis shown in the previous chapters.

4.6.7.2 Applied Phonology: Suggestions for Teaching Pronunciations

It is assumed that learners will make errors when they encounter various types of diphthongs. If these diphthongs are introduced without any description or a focus in exercises, transfer effect may be more easily occur. Specifically, errors will be found in the pronunciation of light diphthongs in unstressed syllable positions. Since English diphthongs are always pronounced long in length, O'odham diphthongs will also be pronounced as long even though they should be short as light diphthongs.[7] For example, like the English *annoy* [ənoy] and *alliance* [əlayəns], O'odham short diphthongs such as [hɨ́gai] will be pronounced by learners as [h$ɨ_{\mu}$g$ai_{\mu\mu}$] instead of [h$ɨ_{\mu}$gai_{μ}], which is correct

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[6] It is also for parents of the endangered languages or anybody who is interested in endangered language education (Hinton 1994).

[7] Almost all diphthongs in English are stressed, exceot [yu]. e.g. value [vǽlyu].

pronunciation. Therefore, a light diphthong in unstressed position is pronounced short in O'odham, and this where learners will make errors.

In the language education of Tohono O'odham, it is easy for learners to not catch such a difference, especially since there is no written indication of the two diphthong types. In order to help learners acquire O'odham sound regarding the two diphthong types, educators first need to know that two different types of diphthongs exist in O'odham. They do not need to teach learners about the two groups theoretically, but they should know how acoustically differentiate the diphthongs that are pronounced in O'odham and English. Such a difference can be incorporated into language teaching method and materials.

Written Materials: textbooks should frequently include words that have unfamiliar sounds to English speakers. The detailed information of phonology does not have to be in the textbooks as long as it is described in teaching manuals. I believe that educators should know what is going on in the targeted language linguistically, so that they can create their own teaching materials focusing on the parts that need to be emphasized. For example, the workbooks may use various words that include light diphthongs in a sentence structure presented in a particular section or chapter.

Electronic Material: education material creators may consider including diphthong differences regarding the weight. Some language education materials already exist. In such materials, learners listen to the correct pronunciation as well as their own, which can be recorded into a computer. For example, a teacher can record students' pronunciation and let them compare their own sound and the native speaker's sound. The screen can show the spectrogram, and even if learners do not have any background in phonetics, they can at least see how their productions differ from native speaker's speech.

Development of such education programs would enhance the teaching and learning of correct O'odham pronunciation that is unfamiliar for English speakers.

4.6.7.3 Need of Second Language Acquisition (LSA) in Tohono O'odham

The study provided above is based on Second Language Acquisition (SLA). When the language maintenance is considered, there is no question that the efforts toward first language acquisition are necessary, because humans acquire language in their early childhood and it becomes harder and harder to do so as they pass their *critical period of language learning* (Lennaburg 1967). This is the hypothesis that a human being possesses a biological time period for being able to acquire a language as their native tongue. In order to increase or maintain the number of first language speakers of Tohono O'odham, it is best to have young children learn the language. In my dissertation however, I deal with second language learners instead of first language learners. It was more accessible to have second language learners than first language learners of Tohono O'odham because the University of Arizona offers the language courses. Children who speak O'odham as their first language were not accessible at the time of my research.

Aside from the accessibility factors, I did my study with my belief that second language acquisition should not be neglected in communities that desire language maintenance. Suppose that a *language nest* immersion program such as that in New Zealand (Hill and Zepeda 1998) is conducted for Tohono O'odham and everybody who undergoes the program starts to acquire O'odham as his/her first language. This will create a gap between the younger generation who speaks O'odham and adults who don't. In real life, there are number of Tohono O'odham members who speak English as their first language and not O'odham. Many of them want to learn the language. Ironically, the desire seems to appear after they pass the critical period. When we do not have a reasonable language education curriculum, it becomes difficult to help even the most motivated members of the O'odham community to learn their language. We should be able to accommodate people who want to learn their traditional language. In this sense, SLA is necessary.

4.6.7.4 Second Language Acquisition of O'odham Phonology

I have shown how a theoretical phonology was applied to second language learners of Tohono O'odham. One might wonder if focusing on phonological SLA is not as important as syntactic SLA, especially when a language is aiming the language maintenance. Of course it is important to teach syntactic structures of Tohono O'odham. However, learning how to pronounce words just like native speakers of Tohono O'odham is part of an identity for the tribal members. This issue may be sensitive among community members because it involves social factors regarding acceptable and unacceptable pronunciation. (cf. Corder 1973). Phonology can help those who care about how to pronounce words of a language "correctly."

First, if we do not consider pronunciation, one who learns O'odham as a second language will have a heavy accent. One might say that speaking a language with an accent is not harmful. It is true, for example, in the case of immigrants to the US. Since most of the immigrants learn English after the critical period has passed, their English pronunciation is generally not native-like. Having accented speech may seem like a minor problem for them as long as they can survive everyday life. However, the English language is not endangered. Even though these immigrants bring accented English into the US, their children who grow up assimilating to the US culture will have fewer problems with sounds because they can be raised in an English speaking environment, resulting in their becoming first language speakers of English.

On the other hand, the situation is different in O'odham. The environment in which the language is spoken is becoming smaller. Tohono O'odham is endangered. Furthermore, members themselves want to "sound O'odham." One hardly acquires the perfect phonology in second language acquisition (Klein 1986). The L2 sound is easily influenced by the phonology of L1. That is, the sound is the weakness for second language learners. It is then plausible to focus on acquisition of sound in L2. So the education of "true" O'odham pronunciation and phonology is necessary.

4.7 Conclusion

In this chapter, I have shown acoustic study of O'odham diphthongs. The classification of diphthongs that were analyzed in Chapter 3 was supported by an applied phonetic experiment using a statistical analysis. In the native speaker's production, the difference between light and heavy diphthongs in unstressed position was statistically significant, but their difference in stressed position was not significant. This showed that these two types of diphthongs were pronounced differently in their duration when unstressed, and there is no such difference in stressed position. On the other hand, in learners' production, differences in these diphthong types are insignificant in neither unstressed nor stressed positions, demonstrating that learners do not make any distinction the native speaker did, resulting in they make learner errors in which light diphthongs are produced in unstressed position.

This experiment carries two main points. One is that the native speaker's production matched the descriptive classification in phonology. The other is that the pronunciation factor found by the experiment with the native speaker is revealed as foreign to the learners of Tohono O'odham. This unfamiliarity may lead learners to make errors. Learner familiarity with unstressed light diphthong differentiation can be a focus in O'odham language education. Kenworthy (1987) makes suggestions for strategies in teaching pronunciation in English. Although I made some suggestions for teaching O'odham in this chapter, creating a handbook for how to teach Tohono O'odham pronunciation similar to her work is something to be considered in the near future.

CHAPTER 5: CONCLUSION

5.1 Summary of the Dissertation

As shown in the previous chapters, three aspects of linguistics are covered in my dissertation: description, theory and application. These fields tend to be studied separately by specialists who focus on their own fields. Nevertheless, I attempted to combine the three aspects of linguistics in my dissertation. This can be considered an example of how linguistic "theory" can contribute to the language education "application".

5.2 The Three Aspects

Several points are made in all aspects. In the descriptive field, I have shown the syllable structure of Tohono O'odham, focusing on weight. O'odham has restriction in onset to be a single consonant, but is flexible with a number of coda consonants. Coda consonant clusters must meet the constrained sonority sequence. A coda is not moraic but it receives only when it is the coda of a monosyllable word containing only one short vowel. There is also a typological contribution. A new classification of diphthong is introduced: light and heavy diphthongs. The categorization does not come from rising vs. falling diphthongs. Rather, it depends on the vowel quality. When it contains [i] it is light, meaning that it can appear in both stressed and unstressed position. When it does not contain [i] it is heavy, meaning it can appear only in the stressed position.

A theoretical contribution is made within the framework of OT. First, I claimed that moraicity is predictable, and that when there is a vowel, a syllable must have at least one mora. This is manifested with the constraint: MI[8] The second theoretical contribution regards moraicity. To the extent that moraicity is not predictable, then it must be indicated in the input, confirming the importance of MAX(μ). Third, I discussed weight shift of a light diphthong depending on a syllable position where it is stressed or non-stressed. Tohono O'odham diphthongs in unstressed position are always light. This has a quality similar to the Stress-to-Weight Principle claimed by Prince (1990). This Stress-to-Weight Principle (SWP) states that a syllable is heavy when stressed, and he mentioned the possibility of having the opposite case that unstressed position must be light as a contrapositive of SWP. In Chapter 3, I focused on the idea of having the vowel quality [i] in a diphthong causes the diphthong to be Light when unstressed. This is manifested in the PD constraint, which deals with the vowel quality of diphthongs besides its position being unstressed. PD could be categorized as a member of the SWP[9] principle, but more research must be conducted to determine such a classification.

As an applied aspect, I have examined one aspect of the second language acquisition of Tohono O'odham and conducted an experimental work involving an acoustic study. I measured the timing of a native speaker's two diphthong categories, and found the difference between the two categories to be significant. I have also shown the timing of learners' speech, noting that learners did not show a significant differentiation between the two groups of diphthongs, making mistakes with respect to their duration in unstressed position. Having pointed out that diphthong duration is a tendency of

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[8] Piñeros (2000) indicates mora in input for regular vowels as opposed to my analysis Chapter 3. His account is shown in terms of mora with respect to the stress assignment for regular and irregular words. This creates an interesting contrast to my account, in which moras are always predictable when regular short vowel. He managed to indicate mora in input for all non-deletable vowels, but this may have been possible because there is no lexical duration difference in Spanish.

[9] I used WSP in Chapter 3 to account for irregularly stressed syllables. Note that WSP and SWP are different in direction (Prince 1990).

learners' errors, a basis for improved teaching methods incorporating the phonological aspect of O'odham is established for educators who develop curriculum or teaching materials.

5.3 Some Inputs

I have had an opportunity to talk about my study in the O'odham language class. The class was in its second semester of elementary Tohono O'odham. Students in the class were usually learning the language with a focus on grammar following the textbook, *A Papago Grammar* (Zepeda 1984). Thus phonological improvement relies on student motivation and is created by listening carefully to their instructor or making an extra effort to reach native speakers outside of the class. There are currently no learning materials provided focusing on the sound system.

I gave a simple lecture on the stress system of O'odham and my findings regarding the diphthongs. After the lecture, almost all students pointed out that they felt learning how to pronounce O'odham was very important. The exception was a student who grew up in an O'odham family. There were other students who grew up in O'odham families but did not grow up speaking or listening to O'odham, and they showed interest in learning the sound system of O'odham.

When one learns a second language, it is an important goal to pronounce words like native speakers. This belief may be stronger in a cultural community like Native Americans because to be able to sound like members is one source of group identity. In order to satisfy this type of motivation, creating language education materials that imply improving pronunciation is helpful. Although the lecture I gave the students was about the system of stress and diphthongs, it is not necessary that students know the technical aspects of linguistic systems. Teachers should know what is happening in the language when they teach the language. Learners do not need specific linguistic information.

5.4 Reasonable Linguistic Study

As I mentioned in Chapter 1, this dissertation is unique for having three aspects in linguistics: descriptive, theoretical and applied. The combination of the different aspects in linguistics must be respected. I have given an example of how these linguistic aspects can be treated with respect to one another. It is reasonable to be concerned with other aspects in linguistics when one researches and pursue his/her interest. Instead of ignoring other aspects, one must consider how linguistics can stand as both science and humanity (Corder 1973).

Native American language maintenance efforts differ from the education of minority students in English. While minority, non-English speaking students experience a change of the basic social unit in which they live (Trueba 1987), O'odham children are already in their culture but not learning the language. This fact may suggest that language maintenance is possible through education providing that the school curriculum is neatly organized with the aim of student fluency in O'odham. Simultaneously, this requirement points out the greatest difficulty in language maintenance because the whole school system must support such curriculum organization.

5.5 Conclusion

Linguistics is a science. Science is developed so that its results contribute to the world. Native American linguistics is sometimes a very sensitive issue because it affects a population whose traditional language is in the middle of language shift that could ultimately results in its extinction. One scientist of economics had a difficult time understanding why I work for language maintenance, when major language education, such as ESL is what was wanted world-wide. For many people, my work may not seem affect many people on a global scale, because the study focuses only on Tohono O'odham. Simultaneously, however, my work is a contributing example for linguists, teachers, speakers, and students of the language. As long as there are people who wish to maintain their tradition, my enthusiasm for Native American linguistics will continue. This can be pursued by improving methodological approaches to experiments with larger populations, developing pedagogical materials, and producing better education for teachers of the language.

APPENDIX A

1 Data Used

The nonsense disyllables listed below are the words I used for my measurement. As shown below, each word has an identification number. Words No. 115 through No. 128 are members of the CVCVV syllable type, and words No. 129 through No. 142 are members of the CVVCV syllable type. Words No. 115 through 122 and No. 129 through 136 contain Light diphthongs and the rest contain Heavy diphthongs.

(1) Nonsense Disyllables

ID No.	WORDS
115	humie
116	hubiu
117	hubio
118	humia
119	hukei
120	hubui
121	hukoi
122	humai
123	hubeu
124	hukeo
125	humea
126	hubua
127	hukoa
128	hukau

ID No.	WORDS
129	kiehu
130	miuhu
131	kiohu
132	biahu
133	keihu
134	buihu
135	koihu
136	baihu
137	meuhu
138	keohu
139	meahu
140	kuahu
141	moahu
142	kauhu

2 Data Measured

The vowel duration measured and their ratios (Chapter 4) between first and second syllables is shown below. The number in the first row is the identification number of the subject. Subjects 1 through 8 are learners and subject 0 is a native speaker.

(2) CVCVV Diphthong in unstressed position

	1.	2.	3.	4.	5.	6.	7.	8.	0.
115	0.22	0.42	0.84	0.44	0.56	0.87	0.42	0.37	1.10
116	0.30	0.48	0.53	0.40	0.40	0.68	0.47	0.31	0.72
117	0.73	0.38	0.67	0.42	0.35	0.64	0.54	0.41	1.00
118	0.48	0.41	0.40	0.42	0.53	0.59	0.58	0.37	0.93
119	0.44	0.26	0.45	0.41	0.89	0.40	0.45	0.27	1.05
120	0.39	0.41	0.29	0.46	0.39	0.78	0.41	0.24	0.99
121	0.25	0.29	0.62	0.26	0.68	0.77	0.37	0.23	0.76
122	0.24	0.33	0.87	0.35	0.33	0.64	0.58	0.22	0.87
123	0.20	0.37	0.47	0.33	0.60	0.58	0.43	0.38	0.66
124	0.40	0.41	0.43	0.39	0.72	0.47	0.47	0.23	0.67
125	0.53	0.34	0.61	0.34	0.56	0.49	0.39	0.25	0.87
126	0.22	0.48	0.82	0.39	0.94	0.57	0.26	0.22	0.73
127	0.23	0.36	0.39	0.28	0.75	0.38	0.38	0.17	0.35
128	0.26	0.29	0.34	0.36	0.27	0.22	0.41	0.30	0.31

(3) CVVCV Diphthong in stressed position

	1	2	3	4	5	6	7	8	0
129	0.68	1.08	1.68	2.19	1.20	1.60	2.46	1.35	1.60
130	2.11	1.63	1.51	1.79	3.45	2.20	1.87	1.97	1.93
131	1.58	1.44	1.81	1.96	1.32	2.00	1.87	1.22	1.61
132	1.80	1.52	1.47	2.35	2.06	2.40	2.12	1.73	1.61
133	1.62	1.56	1.33	2.00	1.81	3.31	1.73	1.43	1.40
134	1.54	1.44	1.56	2.82	1.52	2.28	1.84	2.73	1.09
135	1.73	1.38	1.65	1.76	1.75	1.92	1.33	1.44	1.76
136	1.40	1.81	1.38	2.25	2.75	2.20	1.71	2.19	1.48
137	1.97	1.99	1.09	2.35	2.42	2.08	1.04	1.74	1.28
138	1.13	1.82	1.36	2.34	1.98	1.34	2.11	1.56	1.08
139	1.18	1.54	1.96	2.35	1.90	4.88	1.47	1.83	1.88
140	1.11	1.54	2.02	1.88	0.93	2.51	1.13	1.59	1.15
141	1.58	1.89	1.70	2.84	1.14	2.39	2.54	1.75	1.55
142	1.62	1.89	1.36	2.62	1.31	2.04	2.37	1.86	1.20

REFERENCES

Alvarez, Albert and Kenneth Hale. (1970) "Toward a manual of Papago Grammar: Some phonological terms,' *International Journal of American Linguistics* 36: 2, 83-97.

Bekku, Sadanori. (1977) *Nihongo no Rizumu.* (Rhythm of the Japanese Language) Tokyo: Kodansha.

Booij, Geert. (1989) "On the representation of diphthongs in Frisian," *Linguistics*, 25, 319-332.

Crystal, David (1980) *A Dictionary of Linguistics and Phonetics.* Oxford; UK: Blackwell Publishers.

Crystal, David. (2000) *Language Death.* Cambridge, UK: Cambridge University Press.

Clements, George N. (1990) "The role of sonority cycle in core syllabification. In J. Kingston and M. Beckman (eds.), *papers in Laboratory Phonology 1: Between the Grammar and Physics of Speech* (pp. 283-333). New York: CUP.

Clements, George N. (1991) "Place of articulation in consonants and vowels: a unified theory," *Working papers of the Cornell Phonetics Laboratory* 5, 77-123.

Clements, George N. and Samuel J. Keyser (1983) *CV Phonology.* Cambridge, MA: MIT Press.

Cole, Deborah. and M. Miyashita (to appear) "Poetic Meter in a Prominence Insensitive Language" Formal Approaches to Poetry and Recent Developments in Generative Metrics Conference proceedings, Oct. 1999.

Corder, S. Pit. (1973) *Introducing Applied Linguistics.* Middlesex, England: Penguin Books.

Cutler, Anne, Jacques Mehler, Dennis Norris and Juan Segui. (1986) "The Syllable's Differing Role in the Segmentation of French and English," *Journal of Memory and Language*, 25. 385-400.

Dixon, Robert. M. W. (1994) *Ergativity*. Cambridge; New York: Cambridge University Press.

Ellis, Rod. (1994) The Study of Second Language Acquisition. Oxford: Oxford University Press

Fitzgerald, Colleen M. (1997) *O'odham Rhythm*. Ph. D. Dissertation. The University of Arizona.

Fitzgerald, Colleen M. (1998) "The Meter of Tohono O'odham Songs." In *International Journal of American Linguistics* 64:1, 1-36.

Fitzgerald, Colleen M. (1999) "Loanwords and Stress in Tohono O'odham." *Anthropological Linguistic*. 4:2.

Fitzgerald, Colleen M. (2000) "Vowel Hiatus and Faithfulness in Tohono O'odham Reduplication.' In *Linguistic Inquiry* 31:4, 713-722.

Fitzgerald, Colleen M. (2001) "Morphemeto-stress principle in Tohono O'odham." *Linguistics* 39 (5): 941-972.

Fitzgerald, Colleen M. and Amy V. Fountain. (1997) "The Optimal Account of Tohono O'odham Truncation." University of Arizona.

Hale, Kenneth. (1959) *A Papago Grammar*. PhD Dissertation, Indiana University.

Hale, Kenneth. (1965) "Some Preliminary Observations on Papago Morphophonemics." International Journal of American Linguistics. Vol.31. 295-305.

Hale, Kenneth. (1983) "Warlpiri and the grammar of non-configurational languages" *Natural Language and Linguistics Theory*, 1, 5-47.

Halle, Morris and Samuel Jay Keyser. (1971) *English Stress: Its Form, Its Growth, and Its Role in Verse*. New York: Harper & Row, Publishers.

Hammond, Michael. (1997) "Vowel Quantity and syllabification in English." *Language.* V73. No.1. 1-17.

Hammond, Michael. (1999) *English Phonology*. Oxford: Oxford University Press.

Hayes, Bruce. (1984) "The phonetics and Phonology of Russian Voicing Assimilation." *Language Sound Structure*. Mark Aronoff and Richard Oehrle ed.

Hayes, Bruce. (1989) "Compensatory Lengthening in Moraic Phonology." *Linguistic Inquiry*, Vol. 20. No 2 Spring. 253-306.

Hayes, Bruce. (1995) Metrical Stress Theory: Principles and Case Studies. Chicago: University of Chicago Press.

Hayes, Bruce. (1996) "Phonetically Driven Phonology: The Role of Optimality Theory and Inductive Grounding." (Milwaukee)

Hill, Jane. (1983) "Language Death in Uto-Astecan." IN *International Journal of American Linguistics*. 49:258-276.

Hill, Jane and Ofelia Zepeda. (1992) "Derived Words in Tohono O'odham." International Journal of American Linguistics V58. 355-404

Hill, Jane and Ofelia Zepeda. (1998) "Tohono O'odham (Papago) Plurals." *Anthropological Linguistics* 40: 1, 1-42.

Hinton, Leanne. (1994) *Flutes Of Fire: Essays on California Indian Languages*. Berkeley, California: Heyday Books.

Hyman, Larry M. (1985.)*A theory of phonological weight*. Dordrecht: Foris.

Ito, Junko Armin Mester and Jaye Padgett. (1995) "Licensing and Underspecification in Optimality Theory," *Linguistic Inquiry*, Volume 26, No. 4, 571-613.

Jelinek, Eloise. (1984) "Empty Categorirs, Case, and Configurationality" *Natural Language and Linguistic Theory*, 2, 39-76.

Katada, F. (1990) On the representation of moras: Evidence from a language game. *Linguistic Inquiry* 21: 641-646.

Kahn, Daniel. (1976) *Syllable-based generalizations in English phonology*. Submitted in Partial Fulfillment of the Requirements for the Degree of doctor of Philosophy at MIT.

Kenstowicz, Michael. (1994) *Phonology in Generative Grammar*. Cambridge: Blackwell Publishers.

Kenworthy, Joanne. (1987) *Teaching English Pronunciation*. New York: Longman Publishing

Kiparsky. (1981) "Remarks on the metrical structure of the syllable." *Phonologica* 1980, W. Dressler. et al. eds. Innsbruck.

Kiparsky, Paul. (1982) "Lexical Morphology and Phonology," *Linguistics in the Morning Calm*, Seoul, Hanshin Publishing Co. p. 3-91.

Klein, Wolfgang. (1986) *Second Language Acquisition*. Cambridge: Cambridge University Press.

Kobayashi, Issa. (1997) *The Spring of my life and selected Haiku*. Translated by Sam Hamill. Boston: Shambhala Publications, Inc.

Kogure, Kumi and Mizuki Miyashita (2000) "Audible Silence: A silent mora in Japanese Verses" Western Conference 1998 on Linguistics proceedings.

Krauss, Michael. (1998) "The condition of Native North American languages: the need for realistic assessment and action." In *International Journal of Sociology of Language* 1998 V.132, pp. 9-21.

Kulemeka, Andrew Tilimbe. (1993) "Bimoraicity in Monosyllabic Chichewa Ideophones." In *Studies in the Linguistic Sciences*. Vol. 23, No. 1.

Ladeforged, Peter. (1982) A Course In Phonetics. Fort Worth, TX: Harcourt Brace College Publishers.

Ladefoged, Peter and Ian Maddieson. (1996) *The Sounds of the World's Languages*. Cambridge: Blackwell Publishers Inc.

Lehiste, Ilse. (1970) *Suprasegmentals*. Cambridge, MA: MIT Press.

Lennaburg, E. H. (1967) *Biological Foundations of Language*. New York: Wiley.

Levin, Juliette. (1985) *A metrical theory of syllabicity*. PhD Dissertation. Massachusetts Institute of Technology.

Lieberman, Philip. (1977) *Speech Physiology and Acoustic Phonetics*. New York: Collier Macmillan Publishers.

Lopez, Daniel. (1995) "Wi'ikam Do'ag/Lonely Mountain." In *Home Place: Contemporary Native American Writing from Sun Tracks*. eds. Larry Evers & Ofelia Zepeda. The University of Arizona Press.

Maddieson, Ian. (1984) *Patterns of Sounds: Cambridge studies in Speech Science and Communication*. Cambridge: Cambridge University Press.

Maddieson, Ian and Karen Emmorey (1985) "Relationship between Semivowels and Vowels; Cross-Linguistic Investigations of Accoustic Difference and Coarticulation." In Ed. K. Kohler, Kiel. *Phonetica* 42:163-174..

Mathiot, Madeleine. (1973) *A Dictionary of Papago Usage*. Vol. 1 and 2. Indiana: Indiana University Publications.

McCarthy, John. and Alan Prince. (1986) "Prosodic Morphology." Ms., The University of Massachusetts, Amhurst and The Brandeis University.

McCarthy, John. and Alan Prince. (1988) "Quantitative transfer in reduplicative and templatic morphology." In *Linguistics in the morning calm* 2, ed. the Linguistic Society of Korea, 3-55. Seoul: Hanshin.

McCarthy John & Alan Prince. (1993) "Prosodic morphology I: constraint interaction and satisfaction", ms., University of Massachusetts. & Rutgers University.

McCarthy, John & Alan Prince. (1995) "Faithfulness and reduplicative identity", in Jill Beckman, Laura Walsh Dickey, & Suzanne Urbanczyk, eds., *University of Massachusetts Occasional Papers in Linguistics* 18, 249-384.

McCarty, T. L. (1993) "Federal Language Policy and Native American Education." In *Bilingual Research Journal*, 17:1&2.

Miyashita, Mizuki. (2000a) "Less Stress, Less Pressure, Less Voice" *Southwest Workshop on Optimality Theory Conference 4 proceedings*. Eds. Maye, Jessica and Mizuki Miyashita. The University of Arizona.

Miyashita, Mizuki. (2000b) 'The Moraic Structure of Diphthongs in Tohono O'odham' In *Linguistics Notes from La Jolla. The journal of the UCSD Department of Linguistics. (LNLJ) 20 SWOT V: Proceedings of the Fifth Annual Southwest Workshop on Optimality Theory*. Boyd, Jeremy, Andrew Hickl, Todd O'bryan, Gina Taranto, and Sarah West, eds.

Miyashita, Mizuki. (2000c) "Sequential Grounding and Consonant-Vowel Interaction." *Coyote Paper* Vol. 10 Fountain, Amy et. al. eds. The University of Arizona.

Miyashita, Mizuki. (to appear) "Weight Asymmetries in Tohono O'odham" Student Conference in Linguistics 11 proceedings.

Miyashita, Mizuki and Laura Moll. (1999) "Enhancing Language Material Availability Through Computer Technology" University of Arizona.

Miyashita, Mizuki, Richard Demers and Delbert Ortiz. (to appear). 'Word Order Freedam in Tohono O'odham: An Instrumental Perspective' Proceeding for Scrambling conference, The University of Arizona, 2000.

Moll, Laura. (1997) "Exceptional stress on Spanish loanwors in Tohono O'odham," ms. University of Arizona.

Pierrehumbert, Janet. (1994) "Syllable Structure and Word Structure: a study of triconsonantal clusters in English" in P. Keating ed., Papers in *Laboratory Phonology* III, Cambridge Univ. Press, Cambridge, UK.168-188.

Piñeros, Carlos-Eduardo. (2000) "Vowel Weightlessness and Stress Retraction in Spanish." ROA 427-1100.

Prince, Alan. (1990) "Quantitative Consequences of Rhythmic Organization." *CLS* 26, 355-398.

Prince, Alan and Paul Smolensky. (1993) *Optimality Theory*. Ms., Rutgers University and University of Colorado.

Saxton, Dean. (1963) "Papago Phonemes" International Journal of American Linguistics. 29.1. 29-35.

Saxton, Dean, Lucille Saxton and Susie Enos. (1983) *Dictionary: Papago/Pima-English, English-Papago/Pima*. Tucson: University of Arizona Press.

Selkirk, Elizabeth. (1984) "On the major class features and syllable theory". In *Language Sound Structure*. Aronoff, M and Oehrle, R. eds. (1984). 107-36. MA: MIT Press.

Shibatani, Masayoshi. (1990) *The Languages of Japan*. Cambridge: Cambridge University Press.

Steriade. (1982) Greek Prosodies and the nature of syllabification. Cambridge. dissertation. MIT.

Stern, H. H. (1983) *Fandamental Concepts of Language Teaching*. Oxford: Oxford University Press.

Trueba, Henry T. (1987) "Introduction: The ethnography of Schooling." in *Success or Failure?: Learning & the Language Minority Student.* Trueba, Henry T. ed. Cambridge, MA: Newbury House Publishers.

Yamamoto, Kenkichi. (1974) *Basho Zen Hokku I.* Tokyo: Kawade Shobo.

Zepeda, Ofelia. (1983) *A Papago Grammar.* Tucson; Arizona: The University of Arizona Press.

Zepeda, Ofelia. (1984) *Topics in Papago Morphology*. PhD. Dissertation. The University of Arizona.

Zededa, Ofelia and Jane H. Hill. (1991) "The condition of Native American Languages in the United States." In *Endangered Languages*, ed. by Robert H. Robins and Eugenius M. Uhlenbeck. PP. 135-155. Oxford: Berg.