THE INFLUENCE OF VOWEL HARMONY ON TURKISH NATIVE SPEAKERS LEARNING AN ARTIFICIAL LANGUAGE SYSTEM

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ÖZET

Altan, Aslı. *Türkçe'yi Anadil Olarak Konuşan Deneklerin Yapay bir Dil Sistemi Öğrenmesinde Ünlü Uyumunun Rolü*, Doktora Tezi. Ankara, 2008.

Bu çalışmada, ünlü uyumu üzerine kurulmuş yapay bir dili öğrenmenin mümkün olup olmadığı araştırılmıştır. Temel soru ünlü uyumunun deneklere kolaylık sağlayıp sağlamadığını araştırmak olmuştur. Bu kolaylık iki açıdan incelenmiştir: sözce üretim kolaylığı ve sistemi öğrenme kolaylığı. Bunu araştırmak için ünlü uyumu bulunan bir dil olan Türkçe'yi konuşan deneklerle test yapılmış ve deney sırasında gördükleri sistemi öğrenmelerinde ünlü uyumunun etkisi olup olmadığı araştırılmıştır.

Sözce üretim hatalarının sesbilimsel kurallara uyduğu literatürde geniş yer tutmuştur (Dell ve diğ. 2000). Buna dayanılarak, deneklerin hatalarında ünlü uyumu kurallarını gözetip gözetmeyeceklerine bakılmıştır.

Deneyde iki temel koşul öngörülmüştür. Birinci koşuldaki sözcükler yuvarlaklık/ incelik açısından ünlü uyumuna göre sınıflandırılmıştır. Bu koşulun içerisinde üç farklı alt grup vardır: ünlü uyumu, ünlü uyumsuzluğu ve karışık grup. Ünlü uyumu olan sözcüklerdeki ünlü sesler kalınlık/incelik ve yuvarlaklık açısından birbiriyle uyumlu; ünlü uyumsuzluğunda ise uyumsuz olan sözcüklerden oluşmuştur. Karışık grupta hem ünlü uyumu olan hem de olmayan sözcükler vardır.

Her gruptaki deneklere bu kurallardan biri çerçevesinde oluşturulmuş 180 adet anlamsız kelime verilmiş ve belirli bir zaman kısıtlaması ile bunları sesli olarak okumaları istenmiştir. Örneğin, ünlü uyumu olan deneklerin göreceği dörtlü bir sözcük seti *debi pogu tuvo dibe* olurken; ünlü uyumsuzluğuna örnek *tido sodi gezu pude'*dir. Üçüncü grupta ise ünlü uyumu içermeyen kelimeler kullanılarak deney süresince öğrenmenin etkisini sıfıra indirmek hedeflenmiştir. Deneklerin deney sırasında sesleri kaydedilmiş ve hatalarda ünlü uyumunu koruyup korumadıkları araştırmak için yaptıkları hatalar incelenmiştir.

Deneydeki ikinci koşul ise ünlülerin yükseklik uyumu olarak belirlenmiştir. Bu koşul Türkçe'de olmamasına rağmen deneklerin deney sırasında öğrenip öğrenemediğini araştırmak amacıyla üretilmiş olup yine üç alt gruba ayrılmıştır: Birinci grup yükseklik açısından birbiriyle uyumlu olan ünlülerden oluşan sözcükleri içeren ünlü uyumu grubudur (ör: *sezo goze kuvi gidu*). İkinci grup ise, yükseklik açısından ünlülerin uyumsuz olduğu sözcüklerden oluşan ünlü uyumsuzluğu olarak tanımlanan gruptur (ör: *fuge tivo sovi kedu*). Karışık grup yine hem yükseklik ünlü uyumu hem de ünlü uyumsuzluğu içeren sözcüklerden oluşmaktadır.

Bir de her altı grup deneğe deneyin sonunda uygulanacak bir test kısmı oluşturulmuştur. Bu bölümde, gördükleri sistemi öğrenip öğrenmediklerini araştırmak için, deneklere 20 çift anlamsız sözcük verilmiştir. Her çiftte yer alan sözcüklerden biri deneyin birinci bölümü sırasında deneklerin gördükleri sözcüklerle aynı kurallarla üretilmiş, diğeri ise o kurallara uymayan bir sözcükten oluşmuştur. Deneklere bu sözcüklerden daha önce gördükleri sözcüklere benzeyeni seçmeleri istenmiştir. Bu şekilde deneklerin cevapları karşılaştırılmış ve hangi sistemin Türkçe konuşan denekler tarafından öğrenilmesinin daha kolay olduğu araştırılmıştır.

Deneyin son kısmında ise, deneklerden deneyden hatırladıkları sözcükleri yazmaları istenmiştir. Buradaki amaç yine deneklerin sözcükleri oluşturan kuralları (ünlü uyumu ya da uyumsuzluğu) öğrenip öğrenmediklerini görmektir.

Sonuçlar deneklerin deney sırasında gördükleri sistemin kurallarına uyduklarını göstermiştir. Denekler dil sürçmelerinde bile gördükleri sistemin kurallarını büyük ölçüde korumuşlardır. Deneklerin sesletim hatalarında dahi belli ortak özellikler tespit edilmiştir. Bu sonuç ünlü uyumu ve ünlü uyumsuzluğu sistemleri gören denekler için doğrudur. Ancak karışık gruptaki denekler daha fazla sesletim hatası yapmışlardır. Bu durum bir düzen olduğu sürece (ünlü uyumu ya da uyumsuzluğu) deneklerin bunu yapay bir dilde öğrenebildiklerini ancak kuralsızlığın denekler için zor olduğunu vurgulamıştır.
Yükseklik uyumu gören deneklerin sonuçları kalınlık/incelik uyumu gören deneklerle karşılaştırıldığında, deney sırasında kalınlık/incelik uyumu gören deneklerin daha başarılı olduğu gözlemlenmiştir. Bu bulgu anadilin etkisini göstermektedir. Kalınlık/incelik uyumu kuralı Türkçedeki ünlü uyumu kurallarına daha yakın olduğundan deneklerde anadilin etkisi olduğu düşünülmektedir. Bu diğer dillerde yapılan çalışmaları (Oh & Cole, 2006; Linebaugh, 2007) da desteklediğinden kalınlık/incelik uyumunun yükseklik uyumundan daha fazla kolaylık sağladığı bu çalışmada da desteklenmiştir.
Deneyin ikinci kısmı olan test bölümü ve üçüncü kısmı olan hatırlanan sözcükler bölümündeki sonuçlar da sesletim hatalarındaki sonuçlara paraleldir. Deney sırasında kalınlık/incelik uyumu üzerinde eğitilen denekler diğer gruplara göre daha başarılı olmuşlardır. Yükseklik uyumunun, kalınlık/incelik uyumu ile karşılaştırıldığında Türk denekler için daha zor olduğu gözlemlenmiştir. Ancak karışık sistem gören deneklerin sonuçlarından, ünlü uyumsuzluğunun bile tutarsız bir sistemden daha kolay öğrenildiği saptanmıştır.
Sonuçlar genel çerçevede değerlendirildiğinde ünlü uyumunun hem sesletimi hem de algıyı kolaylaştıran bir kural olduğuna işaret etmektedir.

Anahtar Sözcükler

ünlü uyumu, Türkçedeki ünlü uyumu, kalınlık/incelik ve yuvarlaklık uyumu, yükseklik uyumu, sesletim hataları, ünlü uyumsuzluğu, yapay dil öğrenimi, anlamsız kelimeleri sesletimdeki üretim hataları

ABSTRACT

Altan, Aslı. *The Influence of Vowel Harmony on Turkish Native Speakers Learning an Artificial Language System*, PhD thesis. Ankara, 2008.

In this dissertation, we elicited speech errors by experiments and analysed them to see what they reveal about vowel harmony. The basic question is whether vowel harmony helps speakers to learn an artificial language system. Vowel harmony can facilitate learning in two ways: ease in speech production or ease in learning the system. The way we looked at this is by testing Turkish speakers whose native language has vowel harmony and analyse whether vowel harmony had an effect in their learning the system. In the experiments, learning effects in an artificial language system was analysed. The question of whether the subjects learned vowel harmony was tested in three ways: firstly, by the diversity and quantity of their speech errors and secondly, by the test phase at the end of the experiment and thirdly by analyzing the words subjects remembered. In the previous studies, it was already attested that speech errors abide by phonotactic rules of the language and the last word has an effect (Dell et al., 2000). Based on this, in this study we investigated whether subjects comply with vowel harmony in their speech errors.

There were two conditions in the experiment. In the first condition, words were categorized as either adhering to backness/ rounding vowel harmony or not. There were three groups in this condition. The first is the vowel harmony group. In this group the words were made up so that each word had vowels which were agreeing with each other in terms of backness/frontness and rounding. The second group was defined as backness/ rounding disharmony and the third group was a mixed one (consisting of both harmonic and disharmonic words). All the subjects were given 180 non-sense words made according to the condition they were trained on. They were then asked to read those words aloud in a time frame while they were recorded. For example, a set of words from harmony set was *debi pogu tuvo dibe;* a set of words from disharmony was *tido sodi gezu pude.* The third group was simply presented with a mix of both harmony and disharmony words in order to eliminate the effect of learning during the experiment. The recordings were then transcribed to see whether subjects maintained vowel harmony in their errors or not.

The second condition in the experiment was height harmony. Although Turkish does not have this property, this condition was used to see whether Turkish speakers would be able to learn this condition which is attested in many other languages. There were again three groups under this condition. The first group was defined as vowel height harmony group where the vowels in the words were agreeing with each other in terms of vowel height (ex. *sezo goze kuvi gidu*). The second group was defined as vowel height disharmony group, made up of words with vowels not agreeing in terms of height (ex.: *fuge tivo sovi kedu*). The mixed group was again a combination of words from both groups.

There was also a test phase given to the subjects in all six conditions at the end of the training phase. In this part, 20 non-sense words were provided to the subjects to test whether they learned the condition they were trained on. One of the words in each set was made up following the same rules as the training phase; and the other word was violating those rules. The subjects were asked to choose the word that was similar to the

words they saw before. In this way, the results of the subjects trained on harmony, disharmony and mixed condition were compared to see which system was easier for Turkish subjects to learn.

In the last part of the experiment, subjects were asked to write down the words they remembered. The aim here was again to see whether the subjects learned the rules (vowel harmony or disharmony) used to create the words they were trained on.

The results revealed that subjects abide by the conditions of the system they were presented with during the experiment. Subjects preserved the system they were trained on even in their speech errors. There were certain patterns in the speech errors of subjects. This finding is valid for both harmony and disharmony subjects. The subjects in the mixed group made more speech errors. This underlies the finding that as long as there is a pattern (whether harmony or disharmony) in the artificial language system, subjects were able to learn it. However, a lack of pattern is difficult for the subjects.

When the results of height harmony subjects were compared to backness/ rounding harmony subjects, it was revelead that backness/rounding harmony subjects did better. This finding points to the effect of native language. Since backness/ rounding harmony was similar to the harmony attested in Turkish, it is claimed that this similarity has an effect. Thus, the finding in previous studies (Oh & Cole, 2006; Linebaugh, 2007) that backness/rounding harmony is more of a facilitative nature than height harmony was also supported in this study.

The findings in the test part and the words remembered part were also parallel to the results in speech errors part. The subjects who were trained in backness/rounding harmony were more successful than other groups. It was observed that height harmony was more difficult for Turkish subjects compared to backness/rounding harmony. But the results of the mixed condition subjects reveal that even vowel disharmony was easier than a lack of pattern.

An evaluation of the results in a bigger framework, points out to the fact that vowel harmony is a property that facilitates both production and perception.

Key words

Vowel harmony, vowel harmony in Turkish, frontness/ backness and rounding harmony, height harmony, speech errors, vowel disharmony, artificial language learning, speech errors in producing non-sense words.

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List of abbreviations

CVC consonant vowel consonant

CVCV consonant vowel consonant vowel

VH vowel harmony

VBH vowel backness harmony

VHH vowel height harmony

UA Uralic Altaic languages

ATR Advanced Tongue root

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CHAPTER I

1. INTRODUCTION

Vowel harmony is a process which is common in many languages. Uralic, Altaic, Finno- Uralic, Dravidian, some African and Central American languages are a few which are known to have vowel harmony. Vowel harmony is a process where vowels in the same word tend to be similar- that is, they share backness, height, ATR features or rounding. In this study, I will adopt the definition given by Hacıoğlu (1994: 48): "vowel harmony can be defined as a process in which vowels in a word agree in relation to a certain phonetic or acoustic feature".

To give an example from Turkish, *siren*, *esir, kadın, ısrar*, *odun* are Turkish words. All the vowels in these words agree with each other in terms of backness and rounding features. However, in a word for example [ü] and [a] or [u] and [e] sound combinations are not possible, since they do not agree in backness and rounding features. Vowel harmony also requires the vowels of suffixes to agree with the root vowel. To illustrate, the plural suffix in Turkish has two variants *–ler* and *–lar*, the choice of which depends on the backness/frontness features of the last vowel in the root. So, when plural suffix is attached to the word *masa* 'table' the suffix will have the back vowel and result in *masa-lar* 'tables'; but if the root is *sepet* 'basket' the suffix will be *sepet-ler* 'baskets'.

1.1. VOWEL HARMONY IN TURKISH

Vowel harmony is probably the most widely known phonological characteristic of Turkic languages. In general terms, vowel harmony can be described as a set of constraints on the co-occurrence of vowels within words (Taylan, 1999). These constraints hold both within a morpheme and across morpheme boundaries. Constraints on the co-occurrence of vowels within a morpheme (usually root morpheme) are also referred as internal vowel harmony, while constraints applying across morpheme boundaries (i.e. affixes) are referred to as external vowel harmony. Vowel harmony in

Turkish has been defined as ‘all vowels agreeing in their specification for backness and all high vowels agree with preceding vowels in their specification of roundness’ (Clements & Sezer, 1982).

Vowel harmony in Turkish is a twofold effect consisting of palatal harmony and rounding harmony (Inkelas et al., 2001). Palatal harmony is defined as a vowel agreeing in backness with the preceding vowel (Inkelas et al., 2001 among others). Rounding harmony, on the other hand, is defined as a high vowel agreeing in roundness with the preceding vowel.

Clements (1977) listed the common properties of vowel harmony systems as follows:

a. vowel harmony is phonologically motivated
b. it is bi-directional, that is roots control the harmony in both prefixes and suffixes.
c. it is obligatory
d. it is unbounded within the domain of the word.

Turkish vowel harmony obeys all the features Clements (1977) outlined for harmonic systems.

1.1.1. Properties of Vowels in Turkish

There are eight vowels in Turkish: *a, e, ı, i, o, ö, u, ü*[1]. These vowels are classified as such:

A. Position of the tongue:

1. High vowels: *i, ü, ı ,u.*
2. Low vowels: *e, a, o, ö.*

B. In terms of rounding (labiality):

[1] Kopkallı- Yavuz (2001) investigated the phonetic properties of [a] in Turkish by analyzing acoustic data from four Turkish speakers. The results of the study indicated that [a] sound in open syllables is pronounced with more closure and more fronting compared to its pronounciation in closed syllables.

1. Non- round vowels: *a, e, ı, i.*
2. Round vowels: *o, ö, u, ü.*

C. Place of the tongue (palatality):

1. Back vowels: *ı, a, o, u.*
2. Front vowels: *i ,e, ö, ü.*

These properties can be observed in Table 1:

Table 1: Turkish vowel chart

	Non-round		Round	
	Low	High	Low	High
Back	*a*	*ı*	*o*	*u*
Front	*e*	*i*	*ö*	*ü*

1.1.2. Internal vowel harmony

In a harmonic root morpheme in Turkish, any one of the eight short vowels may occur as the vowel of the initial syllable, but there are strong restrictions on what the vowel(s) in the subsequent syllable(s) may be.

Given the initial vowel of the root morpheme as any of the eight vowels the possibilities of what the second vowel may be is illustrated below (Taylan, 1999):

Front vowels:

i-i inci

i-e inek

e-e elek

e-i erik

ü-ü ütü

ü-e tümen

ö-ü köpük

ö-e ördek

Back vowels:

ı-ı ılık

ı-a sıcak

a-a ayak

a-ı acı

a(+labial)-u pamuk

u-u kutu

u-a yulaf

o-u koyun

o-a oda

Though the [a C u] sequence when the intervening consonant is a labial one has been given as the morpheme structure condition of labial attraction, there seem to be too many examples in the Turkish language that would constitute exceptions to this condition (Taylan, 1999: 45). One set of exceptions comprise roots where [a] is followed by [u] though the intervening consonant is not a labial one, as can be observed from the examples *marul, kanun, kiraz, hatun, sahur.*

The exemplary set provided above illustrates that once the initial vowel is specified, then there are only two alternatives for the choice of the following vowel. In each case, the second vowel can either be a high vowel or a non-high vowel. Thus the height of the non-initial vowel is not predictable but all other features, like frontness and backness and rounding are predictable.

As suggested by Taylan (1999), the constraints on internal harmony can be stated as follows:

1. The first vowel of the morpheme is the determining factor, the vowels of the subsequent syllables agree in frontness and backness with it.
2. If the second syllable of the root morpheme has a high vowel, then it agrees in rounding with the preceding vowel (i.e. the vowel in the first syllable)
3. Mid rounded vowels do not occur in non-initial syllables. Thus, rounding is not a feature of the whole word but palatality (i.e. frontness and backness) is;

rounding is observed only in instances where a high vowel follows a labial (rounded) vowel.

Given these generalizations, it means that once we know the height of the second vowel in the morpheme, we can predict all its other features. For example:

a) goncV (-high)
b) yörVk (+high)

In example (a) above, since we have a non-high second vowel, it can only agree in frontness or backness with the preceding vowel. The first vowel is a back vowel, so the second vowel has to be a non-high, unrounded back vowel, which is [a], thus we get *gonca*. In (b), the second vowel is a high vowel, so it will agree in rounding as well as frontnesss and backness with [ö], the vowel of the first syllable. Therefore, the second vowel will be high, rounded and front, which is [ü]; thus the word is *yörük*.

The Turkish language seems to be quite lenient to disruptions of internal vowel harmony, in the sense that many commonly used root morphemes, majority being loanwords that do not abide by vowel harmony rules are tolerated without any problems, such as *kalem, pilot, kitap, bahçe, inanç, memur* etc. Compound words also violate vowel harmony as can be seen from the examples: *açıkgöz, bilgisayar, çekyat, hanımeli*. There are also a set of suffixes that violate vowel harmony as *-gil, -ken, -leyin, -mtırak, -yor* as observed from the words: *akşam-leyin, bakla-gil-ler, çalışır-ken, ekşi-mtırak* and *yürü-yor.*

1.1.3. External Vowel Harmony

All suffix vowels agree with the immediately preceding vowel (the last vowel of the root) with the features of frontness /backness. If the vowel in the suffix is high, then this vowel will also agree with the feature rounding of the immediately preceding vowel. The principles of internal vowel harmony are also operating here.

ev-ler	*ev-in*
av-lar	*av-ın*
diş-ler	*diş-in*

kış-lar	*kış-ın*
gül-ler	*gül-ün*
kul-lar	*kul-un*
göl-ler	*göl-ün*
kol-lar	*kol-un*

The height feature has to be specified for the non-initial vowel of the root morpheme in internal vowel harmony, the vowels of the suffix has to be specified for height as well. Then, their features of frontness/backness (palatality) and rounding (labiality) are predictable by external vowel harmony rules.

The external vowel harmony rule seems to be more compelling a rule than internal vowel harmony. Even with non-harmonic root morphemes, external vowel harmony applies as expected and the suffix vowel agrees with the immediately preceding vowel in the features as in *pizza-lar, paket-ler, televizyon-un* and *polis-in*. It is interesting to note that suffixes following a non-harmonic suffix undergo external vowel harmony as well: *bakla-gil-ler, gel-iyor-dum, okul-da-ki-ler.*

There are, however, exceptions to the external vowel harmony rule some of which are predictable and others which are unpredictable. Some examples to exceptions:

(a) *hol-ü*

rol-ü

gol-ü

hilal-i

nal-ı

sembol-ü

sol-ü

kabul-ü

golf-ü

(b) harf-i

harb-i

saat-i
hakikat-i
istirahat-i
iştirak-i
kanaat-i
ziraat-i
sıhhat-i

All the words above have a back vowel as the final vowel of the root, but those in group (a) end in a palatal [l], which triggers the fronting of the following suffix vowel. Those in (b) unpredictably require a front vowel in the suffix, and thus are exceptions to the external vowel harmony rule.

1.2. STATEMENT OF THE PROBLEM

The sound patterns of a language are embedded in its words. Speakers learn the sound patterns as they hear and say words, and the acquired knowledge of the sound patterns affects their phonological behavior in turn. For example, speakers can tell whether a novel sound sequence can be a word in their language. Further, in perceiving and producing speech sounds, they are biased towards those that occur in contexts that follow the sound patterns of their language. For example, there is no word in English that starts with /ŋ/, and therefore speakers never hear or say words in English that start with /ŋ/. As a result, native speakers of English do not consider sound sequences that start with /ŋ/ as possible words in English, and they rarely make speech errors that result in sound sequences that start with /ŋ/ (Dell et al., 2000).

The learning of sound patterns and the resulting change in a speaker’s behavior is often described as the adaptation of their *phonological processing system* (Chambers, 2003; Whalen and Dell, 2006), defined in Snowling (2004) as one component of the language processing system that is “concerned with how speech sounds are perceived, coded, and produced”.

In this study I investigate whether vowel harmony is such a pattern for Turkish speakers. There has been no previous research which exclusively concentrates on the question whether the presence of vowel harmony can help speakers speaking a vowel harmony language in learning an artificial system defined on harmony. Previous studies focused more on the theoretical implications of vowel harmony. In addition, there are no experimental studies on vowel harmony in Turkish. In this study, I test whether vowel harmony is a principle that helps Turkish speakers in learning an artificial language system.

1.3. PURPOSE OF THE STUDY

The aims of this study are to describe how native Turkish speakers learn vowel harmony in an artificial language system, presented to subjects by an experiment to be described in detail in the method section, and to account for their speech errors based on different language systems they are subject to, by adopting a psycholinguistic approach. The ultimate aim is to see whether vowel harmony is a more natural phonological system compared to vowel disharmony or no coherent pattern. To test this, both backness/ rounding harmony (similar to the Turkish vowel harmony) and height harmony were used. If Turkish speakers were found to be sensitive to vowel harmony, then they would have less difficulty pronouncing the words in the vowel harmony sets (both in backness and height harmony) and they would learn the rules of the artificial system more easily.

This study seeks to discover whether vowel harmony facilitates speech production. I speculate that, if found, the facilitative effect is likely attributable to economy in motor articulation or economy in speech planning. A facilitative effect is to be found if made up words with harmonic vowel combinations can be produced more quickly or with fewer errors (or both more quickly and with fewer errors) than made up words with disharmonic vowel combinations. Specifically, I test whether back harmonic and height harmonic vowel combinations can be produced more quickly or with fewer errors than vowel combinations that are disharmonic with respect to those features. If the answer is yes, it is likely that the benefit to production lies in reduced muscular effort in articulation of harmonic vowel sequences or in advantages in speech planning related to production.

The claim that economy in motor activity or ease of articulation plays a role in the formation of phonological patterns is not new or uncommon. Jesperson (1942) says a tendency towards economy of effort is evident in all human behavior and should be taken into account in the explanation of sound changes. Blevins (2004:72) cites Baudouin's (1897/1972) declaration that "…the impulse for all linguistic change, is a tendency toward convenience, toward a minimum of effort…". Blevins (2004) also cites Grammont (1933) who proposed a "law of least effort". Grammont thought such a law played a major role in the evolution of languages, and that all assimilation changes could be attributed to it.

According to Hock (1991), 'the lazy tongue phenomenon' or a reduction of articulatory effort is the most likely explanation for sound changes involving lenition. Such sound changes include intervocalic voicing, fricativization, degemination, rhotacism, and flapping. Kirchner (2004) also believes patterns of lenition are directly attributable to efforts to minimize articulatory effort. A reduction in effort has also been proposed as an explanation for Grassman's Law which allows only one aspirated consonant in a word in Sanskrit and Greek. Ladefoged (1984) suggests that aspirated consonants are costly in the sense that they require high levels of respiratory energy. A word with two aspirated consonants would be very costly in terms of energy use, and the dissimilation that came about had the effect of reducing the overall effort required.

In a more global sense, the fact that sound changes involving reduction of articulatory effort greatly outnumber changes that involve the introduction of new articulatory material has been cited as evidence that sound change is reductive in character (Bybee, 2001; Mowrey & Pagliuca, 1995). Ease of articulation is central to the ideas put forth by many scholars working within Optimality Theory. In Hayes (1999: 254), language learners are seen as being able to assess the difficulty of specific phonological demands using measures such as articulatory force or energy expenditure. Learners are able to determine the characteristic difficulty of particular phonological configurations and use that information to construct “a phonetic map of the space of articulatory difficulty”. Flemming (2002) suggests that a class of effort minimization constraints inhibits longer distance articulatory movement.

According to Hayes and Steriade (2004), phonological processes such as cluster simplification, place assimilation, lenition, vowel reduction, and tonal neutralization can be traced to ease of articulation. Jun (2004) and Kirchner (2004) cite ease of articulation constraints as essential in explaining assimilation and lenition, respectively. Constraints that require minimizing articulatory effort are ranked against constraints that require the preservation of contrast.

The experiment described in this chapter is designed to see if it is possible that ease of articulation could be a factor in the development of vowel harmony (VH, hereafter). Lewis (1967) asserts that such is the case, saying that vowel harmony is attributable to a reduction of muscular effort. Suomi (1983) cites Hakulinen (1968) as portraying palatal vowel harmony being motivated by a reduction in terms of movement of articulators. Pulleyblank (in press) argues that articulatory inertia leads to vowel harmony. VH arises because languages try to minimize the resetting of articulators. The fact that vowel harmony is more common in the speech of children learning language provides some support for this idea. Drachman (1978), Smith (1973), and Drachman (1972) cite a tendency toward vowel harmony in the speech of children. This is true of children learning languages that do not exemplify vowel harmony in adult speech.

Given these facts, trying to learn if vowel harmony does indeed in some way facilitate production is quite justified. However, facilitation, if it exists, may not be solely attributable to the physical fact of ease of articulation. It is possible that a facilitative effect derived from vowel harmony can be traced to economy in speech planning.

In the present work, as will be described in detail in the following method section, an experiment was conducted to test whether vowel harmony facilitates speech production. If a facilitative effect exists, it can be taken as support for the ease of articulation argument and/or economy in speech planning. In this experiment, subjects were recorded as they produced nonsense phrases quickly. The nonsense phrases were classified as back harmonic, height harmonic or disharmonic, depending on the vowel combinations in the words. My hypothesis was that subjects would produce back harmonic and/or height harmonic phrases more quickly or with fewer errors when compared to disharmonic phrases. Such a finding would be evidence of a facilitative effect of vowel harmony.

The current study only aims to investigate tongue-body vowel harmony (TBVH). TBVH includes vowel backness harmony (VBH) and vowel height harmony (VHH). Other types of vowel harmony that do not involve tongue body features, such as ATR harmony, nasal harmony and roundness harmony are not part of the investigation. Roundness harmony is discussed only as it relates to backness harmony.

1.4. RESEARCH QUESTIONS

In parallel with the aims of the study, the following research questions will be answered by using an artificial language experiment.

1.4.1. About Harmony

1. Is it easier for Turkish speakers to learn an artificial system with vowel harmony compared to a system that lacks it?
2. Are the subjects going to make fewer speech errors in the harmony condition since it is phonologically more similar to their native language?
3. In case the subjects make speech errors, to what entent are such errors related to vowel harmony? That is, if the subject is subject to a vowel harmony system, will his/her errors still adhere to vowel harmony?
4. If the new system the subjects are trained on employs a different type of vowel harmony, such as height harmony, will the speech production display similar phonological characteristics as in the vowel harmony system?

1.4.2. About Disharmony

5. Are subjects presented with a system that is defined with disharmony going to make more speech errors?
6. If the subjects make speech errors, will these errors obey the system they are trained on?
7. Can an artificial language system be learned even if it is based on disharmony?

1.4.3. About the Mixed System

8. Are Turkish speakers prone to vowel harmony? That is, if they are not presented with a system that lacks a coherent pattern (either harmony or disharmony) will they have a bias towards vowel harmony?

1.4.4. Broader Questions

9. Will Turkish speakers learn the system they are presented with, whether it is of vowel harmony or disharmony?
10. Which subjects will make more consonant errors, the harmony subjects, disharmony subjects or the mixed group?
11. When subjects are asked to remember the words they saw during the experiment, will the words they remember adhere to the condition they are trained on? If they write down words that they did not actually see, will those words still adhere to the condition they are trained on?
12. Are speech errors of subjects parallel to the phonotactic constraints of their language?
13. Is there any difference between height harmony and backness/ rounding harmony? Can one of these said to be simpler or easier to learn when compared to the other? If one of them is easier, why? Is there an effect of native language?

14. If there occurs any difference between backness and height harmony systems in the artificial language system, what does this imply about the different types of harmony in natural languages?

1.5. METHOD

To investigate the role of vowel harmony in learning an artificial system, an artificial language experiment adapted from Dell et al. (2000) was employed. The experimental method was similar to Dell et al. except that the focus was on speech errors involving both vowels and consonants, rather than only consonants. In each experiment, speakers pronounced sequences of four disyllabic nonsense words under time pressure, a procedure which resulted in many vowel errors. Across participants, the nonsense words either obeyed a typical vowel harmony constraint (rounding/backness or height harmony) or observed a reverse vowel harmony constraint (disharmony) or reflected no vowel constraints. Knowledge of the harmony constraints was assessed both via an explicit forced-choice test, the analysis of the words subjects remembered and by examining the nature of the speech errors that were pronounced.

1.5.1. Participants

72 undergraduate students, between ages 18-24, from Hacettepe University participated in the experiment. All subjects were native speakers of standard Turkish. There were 12 subjects in each condition (being harmony, disharmony and mixed). There were a total of 36 participants in the backness/ rounding harmony and another 36 in the height harmony.

Each subject was given a number that indicates the order they took the experiment together with the condition they were trained on. To illustrate, subject 12BH indicates that she/he is the 12th subject and was trained in the backness harmony condition; 35HD indicates that the subject was the 35th subject in the experiment and was trained in height disharmony.

1.5.2. Experiment Design

Each experimental session consisted of four phases presented to the subjects in the same order: A practice phase, a training phase, a test phase and a final part where subjects were asked to write down the words they remembered.

The computer program FLEXLAB was used to generate and present the items to the subjects. This program lets the subject have the command of the computer once it is initiated by the experimenter.

Most subjects completed the experiment in less than 45 minutes, and no subject took more than 50 minutes. Subjects were recorded using a Sony TCM -5000EV tape recorder connected to an Audio-Technica ATR20 microphone.

In order to avoid distractions, the experiment took place in an isolation booth. Only the subject and the experimenter were present. Subjects gave their consent to participate in the experiment at their own will by signing a consent form, and were not compensated for their participation.

1.5.2.1. Practice and Training Phases

During the practice and training phases, participants were presented with four words, appearing one at a time on a computer screen and were asked to pronounce them. Each quadruple was presented once. The subjects also had a training part on how to pronounce the sounds used in the experiment with one syllable words which were not used on the actual experiment. A timing bar was also presented under the word pair to indicate how quickly the words should be pronounced; the timing bar filled up in four steps, and participants were told that they should pronounce one word for each step. When the timing bar was full, a new screen with four new words would come up automatically.

In the practice phase, the duration of each step was kept constant at 900 ms. During the training phase, the step duration began at 632 ms and decreased by 4 ms with each pair. Encouraging the participants to pronounce the words rhythmically helped them keep approximately equal stress on each word.

1.5.2.2. Test phase

The second part of the experiment was where the subjects saw pairs of non sense words on the screen made up according to the rules described earlier. One of the words was a word which was generated by using the same rules that were used to generate the harmonic test items (either backness/ rounding or height harmony). The other word was the same type of item as the disharmony words. A randomly chosen 20 items from each condition had been left out from the list to be used in this part. The disharmonious ones in the backness/ rounding set were generated by replacing the front vowel in the words by a back vowel so that it always violated vowel harmony. The disharmony words in the height harmony experiment were generated in such a way that vowels constantly had different height properties.

The subjects saw a pair of words on each screen one of which is harmonious and one disharmonious. They were then asked to choose which one of the two words sounds like those they saw on the training phase. The subjects were encouraged to say the words aloud and they pressed a button to indicate their choice. For each word they listened to, subjects were asked to press ‘F’ on the keyboard if the word on the left looked/ sounded like the words they saw and pronounced in the training phase and press ‘J’ if the word on the right looked/sounded like the words they saw/pronounced before.

The subjects in all three parts (harmony, disharmony and mixed) of the same condition saw the same test items, except that the order they saw was randomized for each subject. Again, the subjects trained in height condition saw the same items in the test phase. A complete list of words used in both backness and height condition can be found in Appendix 7 and 8, respectively. Since each subject saw the words in a different order, any other effects were eliminated.

1.5.2.3. Words remembered

In this section, subjects were given a separate sheet of paper where they were asked to write as many words as they could remember form the words they saw in the training phase.

The experiment was self-paced in that subjects regulated the amount of time they needed. They did not have a restricted time period, they handed in the paper when they finished writing. Subjects were told that it was acceptable to take a break at any time, but none of the subjects took a break for more than one or two minutes. Most subjects completed this part of the experiment in about 5 minutes, and no subject took more than 10 minutes.

1.5.3. Materials

The experimental items consisted of CVCV nonsense words. For all of these words, the consonants were drawn from [p], [b], [t], [d], [k], [g], [f], [v], [s], and [z], with the constraint that the voiceless consonants ([p], [t], [k], [f], and [s]) were only used in the word-initial position. This was done to keep the features of the consonants constant among all items since a voiceless consonant between two vowels was very likely to be pronounced as its voiced counterpart. The consonants were limited to stops and fricatives because these had a minimal impact on the pronounciation of the adjacent vowels. As previous studies (Luce, 1986 & Luce et al., 2000) report, there is empirical support from experimental setting that liquids are more likely to be confused with each other than the high vowels. Theoretical support comes from Frisch et al. (1997) whose similarity metric suggests that the liquids are phonologically more similar to each other than the high vowels. This is why liquids were avoided when constructing the words.

Consonants were not repeated within a word. Each consonant was used once in a made up word. The strings were formed such that two words beginning with the same consonant would never follow each other.

Table 2: Vowels used in the experiment

	Front	**Back**
High	[i]	[u]
Mid	[e]	[o]

The vowels were drawn from the set [e], [o], [u], [i], with the constraint that both vowels in a word must come from the same "class". In backness harmony condition, for half of the words, the classes were ([e], [i]) and ([o], [u]). So, [e] and [i] were used in a word and [o] and [u] was used in another word. These words constituted the backness harmony items, as the vowels within a class had the same value for both backness and rounding. The only variable that differentiate [e] from [i] and [o] from [u] is height. For the other half of the words, the classes were ([e], [u]) and ([i], [e]). These words constituted the backness disharmony items, as the vowels within a class had different values on both the backness and the rounding features. The use of [i] and [u] or [e] and [o] in the same word for backness disharmony words was avoided since that would result in height harmony. Only tense vowels were used, as lax vowels generally do not occur in CV syllables in Turkish. In both backness harmony and disharmony conditions the vowels differed in height. As with consonants, vowels were never repeated within a word.

For creating height harmony words, the same vowels were used but combination of vowels within a word were different. For height harmony set, vowels [i] - [u] and [e] - [o] were used together in a word since they agreed in height. For height disharmony, [e] - [u] and [o] - [i] were used together since they did not share the feature height, thus defined as disharmonic in terms of height harmony.

There were 180 harmony words and 180 disharmony words that satisfied these constraints in both backness harmony and height harmony conditions. 20 harmony words and 20 disharmony words had been randomly chosen to be used in the test phase of the experiment with the constraint that there were five words with each possible pairing of vowels (e.g., for the backness harmony condition, [i] and [e], [e] and [i], [u] and [o], [o] and [u]). For the remaining harmony and disharmony items, harmony quadruples and disharmony quadruples were created by randomly pairing harmony words and disharmony words. 80 quadruples were chosen by randomly picking one word with each possible pattern of vowels. Each word appeared in exactly two quadruples. Because these created only 180 words and we had 360 words in the experiment, each word appears in exactly two quadruples. This was done on prupose since it was found in previous studies that speech production is facilitated when a syllable or a word is repeated (Sevald & Dell, 1994). However, quadruples which have the repetition of the same word coming one after another were avoided. In order to control for the effect of whole syllable repetition, stimuli in which the same vowel is repeated in a word are excluded. Thus, there are no items such as *bebe.*

Not only the order of quadruples but also the order of the words in the quadruples was randomized. So, each subject saw the words in a different order to avoid any effect of order in their performance. Example items from backness harmony condition are shown in Table 2. A list of all words used in the experiment in different conditions can be found in Appendix 1, 2, 3, 4, 5, 6. Thus, all pairs contained all four vowels, but the harmony and disharmony pairs differed in which vowels occurred together within a word.

Table 3: Sample items (in the same transcription as to be presented to the subjects)

Harmonic items	**Disharmonic items**	**Mixed items (harmony & disharmony)**
sebi zogu fuzo vize	vezu fuze vizo kogi	bive fevi dogu tuzo
guvo dize tegi vozu	segu fude zivo godi	kuvo give tebi bovu

zibe bezi bogu vugo	dezu tuve bido fogi	fube bido zobi pegu
pide febi vobu budo	kube zido vobi sedu	kigo fegu bozi kude

Each set of 80 pairs was randomly ordered to form two training lists, a harmony list and a disharmony list. In addition to these lists, an additional five pairs were generated to serve as practice items. These pairs were created by randomly selecting ten experimental items and modifying them so that either a consonant was repeated within a word, or one of the consonants was replaced with a consonant other than those used for the experimental items (e.g., [m], [n]). The same set of practice items were used for all both lists. In the practice phase, subjects were trained to make sure they pronounced the vowels with the desired quality.

Finally, twenty test items for both backness harmony and height harmony were created by pairing one harmony word and one disharmony word from the set of words set aside earlier. The order which the subjects saw the words was also randomized so that each subject saw the words in a different order. In this way, any possible effects of order were eliminated.

1.5.2. Scoring

The audio tapes recorded in each session were played back, and each trial was coded by the experimenter as either successful or having an error.

An error was defined as production of an incorrect vowel, an incorrect consonant or not saying the complete item. Other disfluencies, such as a long pause, were not counted as errors. It is possible that disfluent production, as well as the production of an incorrect vowel, were influenced by the harmonic status of a vowel sequence, but it was theorized that the effect of disfluencies such as pauses and repetition of syllables would be seen in differences in the number of words produced at each trial. Since, the aim was to say all the four words in each screen the the allotted time, such pauses would effect the performance.

A second coder was recruited to assess coding reliability. Agreement between the two coders was tested for 400 trials from five subjects in harmony condition and five subjects from the disharmony group. The second coder was uninformed as to the purpose of the study and she did not speak Turkish as a native language. The two examiners independently marked each sound change and each omitted word and comparing these to the marking completed during the experimental sessions. The two coders agreed on the absence or presence of an error 98.25% of the time. There was no evidence of bias on the part of the coder who was aware of the purpose of the experiment. The net effect of using the unaware coder's error count rather than that of the primary coder would be an increase of one error in the height harmonic condition, and no change to the error count in the other two conditions.

a. The errors for harmony[2] subjects trained in backness harmony were categorized as:

1. Consonant errors (which shows the error rate)

   A. Switching the order of consonants:

   ex. **fib**e **-->** **bif**e

   B. Repeating the first consonant:

   ex: fi**b**e **-->** fi**f**e

   C. Not pronouncing the word / half of the word:

   ex. fibe **-->** ∅ / fi

2. Errors in the vowels:

   a. Keeping the first vowel and replacing the second vowel with it

      ex. fob**u** **-->** fob**o**

   b. Keeping the second vowel and replacing the first vowel with it.

      ex: f**o**bu **-->** f**u**bu

   c. Switching the order of the two vowels within the word

[2] The errors for height harmony subjects were also categorized under the same heading, the examples here are all given from backness/ rounding harmony for the sake of simplicity.

ex: f**o**b**u** **-->** f**u**b**o**

d. Creating disharmony

ex. f**o**bu **-->** f**e**bu

e. Substituting another vowel that is not one of the four vowels we used

ex. fob**u** **-->** fob**a**

b. The errors for disharmony subjects trained in backness harmony were categorized as:

3. Consonant errors (which shows the error rate)

   Switching the order of consonants, repeating the first consonant etc.

4. Errors in the vowels:

   a. Keeping the first vowel and replacing the second vowel with it

   b. Keeping the second vowel and replacing the first vowel with it.

   c. Switching the order of the two vowels within the word

   d. Changing both vowels

   e. Creating harmony

   f. Substituting another vowel that is not one of the four vowels we used

c. The errors for mixed condition subjects trained in backness harmony were categorized as:

1. Consonant errors (which shows the error rate)

   Switching the order of consonants, repeating the first consonant etc.

2. Errors in the vowels:

   a. Keeping the first vowel and replacing the second vowel with it

   b. Keeping the second vowel and replacing the first vowel with it.

   c. Switching the order of the two vowels within the word

   d. Changing both vowels

   e. Creating harmony

   f. Creating disharmony

   g. Substituting another vowel that is not one of the four vowels we used

1.5.2. Statistics

Two different statistics were applied to the results of the data. The first is the Kruskal-Wallis test which was used to determine whether there are significant differences between the three groups trained in each condition (backness and height harmony). This test compares the difference between mean ranks and the medians of the results of each group. It evaluates whether the population medians on a dependent variable are the same across all levels of a factor. With the K independent samples test, Kruskal-Wallis test, a chi-square statistic is used to evaluate the differences in mean ranks to assess the null hypothesis that the medians are equal among groups.

The second statistics test used was the the non-parametric, two independent samples test Mann-Whitney-U test. The Mann-Whitney-U test evaluates whether the medians on a test variable differ significantly between two groups. Mann-Whitney-U test was used so that groups are compared to each other in two-way comparisons.

CHAPTER 2
REVIEW OF LITERATURE

In this section, I will summarize the studies on vowel harmony under four headings:

1. Studies on vowel harmony 2. Studies on vowel harmony in Turkish 3. Studies on speech segmentation in other harmonic languages 4. Studies on artificial language learning.

2.1. Studies on Vowel Harmony

Hyams (2002) compared vowel and consonant harmony by analyzing VH in different languages. He suggested that they show the same directionality properties, except three conditions: 1) vowel harmony is more sensitive to reduction than consonant harmony. 2) Consonant harmony may apply to underlying contrastive consonants while VH is typically non-neutralizing. 3) Crosslinguistically VH appears to apply progressively than regressively and suffixation is far more common than prefixation.

Walker (2003 and 2006) and Kaun (2004) worked on the theoretical aspect of vowel harmony. Walker supports the view that vowel harmony may facilitate the production of language and Kaun supports the view that it eases perception (Kaun, 2004).
According to Kaun (2004), vowel harmony helps perception since it extends the duration of a vowel property that is difficult to identify. In Kaun's account, vowel harmony is a perceptually driven phenomenon that serves to prolong the duration of a feature or quality. She suggests that "vowel harmony provides the listener with increased exposure to the feature value in question" (Kaun, 2004: 15). In her view, harmony gives rise to perceptual enhancement at the cost of reducing the number of possible words in the language. Since the vowel value is identified once in the string and it is constant, the acoustic dimension which is associated with the harmonic feature need no longer be attended to, rather attention may be focused on other aspects of the acoustic symbol. If only a tentative identification of the harmonic value feature is made early on, the remainder of the string has additional verification. If somehow the acoustic

cues in the first part of the string are obscured, the information is still potentially recoverable from the information in the latter part.

Kaun (2004) also talked about the gestural uniformity principle in her paper which says that cross-height harmony has to be avoided. So, the rounding gesture is not always the same for all rounded vowels. High vowels have a different rounding. The rounding for non-high vowels requires less lip activity. Kaun cited an experiment by Boyce (1988) which tested whether there was a difference between vowel-to-vowel co-articulation in English and Turkish *uCu* sequences. Turkish, being a rounding harmony language, represents *uCu* as containing a single [round] feature multiply linked to both vocalic positions. English, which lacks rounding harmony, represents the same sequence with two independent [round] specifications. The English-speaking subjects attained a position of protrusion in the articulation of the first rounded vowel, then receded during the articulation of the consonantal sequence, then once again attained a position of protrusion for the second rounded vowel. However, the Turkish articulatory pattern turned out to be different. The results obtained by Boyce showed that Turkish speakers had a "plateau"-like pattern in the articulation of *uCu* sequences. So, the English speakers executed two lip rounding movements, the Turkish speakers executed only one. This indicates that the distinct phonological representations result in distinct phonological behaviour. Kaun concluded from these results that if Turkish pattern represents harmony languages, then a single [round] autosegment in the phonology corresponds to a single lip rounding in phonetics. Gestural Uniformity is the principle that regulates the production of multiply-linked structures in a way that dictates the execution of a single autosegment or articulatory instruction which should be achieved by a uniform articulatory posture.

Kaun (2004) lists the five conditions favouring rounding harmony as:

- the trigger is non-high
- the trigger is high
- the target is high
- the target is back
- the trigger and target agree in height

Kaun (2004) proposes that non-high vowels and front vowels are perceived as relatively less rounded. So, the lip rounding is not the same for all rounded vowels.

In short, this is a comprehension account of vowel harmony which is based on perception rather than production.

Walker (2007) supported the agreement by correspondence theory which claims that the occurrence of highly similar consonants stimulates a relation formed between them which is named as a correspondence relation in phonological theory. Functional origins of this relation are said to lie in the area of planning and execution of speech. The author reported that it is widely agreed that "similar" consonants are more prone to participate in speech errors, this study investigated "whether the categories of similar consonants identified by long-distance nasal agreement are the same as those witnessed in patterns of error production" (Walker, 2007: 4). This paper demonstrated several parallels between long-distance consonant agreement and speech errors. The prediction is that highly similar consonants are more likely to interact with each other in long-distance agreement and thus participate in errors. There were three experiments which were conducted on the basis of the hypothesis that "the consonants which are more similar to nasals according to the scaling suggested by patterns of long-distance nasal agreement will show higher participation in speech errors with nasals in languages that do not have nasal agreement." (Walker, 2007: 14). In each of the experiments there were sub-hypothesis where the assumption was that higher similarity correlates with more errors. Each experiment tested an aspect of similarity: In Experiment 1, similarity in voicing, in Experiment 2 similarity of place of articulation and in Experiment 3 similarity in manner of articulation was tested. All experiments used the SLIPS technique, which employs phonological priming to generate initial consonant ordering errors. The experiments showed that long-distance agreement has functional origins in facilitating language production. The consonants that participated in speech errors are interpreted as more similar than those that participated less. It seems that similarity has a big influence on speech sounds' potential to interact in certain phonological processes. Sounds that are minimally different present difficulties in speech planning, they lead to misordering and substitution errors. They also lead to speech execution errors. Walker reported that it has been demonstrated in the previous research that all kinds of long-distance agreement favor interactions between consonants with a high degree of similarity (Hansson 2001; Rose & Walker, 2000). Walker's research can be linked to vowel harmony in that vowel harmony is also a process that makes the production of words easier. Vowel harmony is basically an assimilation process. The presence of vowel harmony makes it easier to articulate words for speakers since it is easier to re-produce something you have already produced. According to this view, the reason languages have vowel harmony is because of constraints on language production. People basically want to keep on producing same or similar sounds for the ease of production. As stated by Walker, speech error research shows that similar sounds pose difficulty in speech production which can be improved by moving towards an identity.

Walker (2006) centered on height harmony in Veneto Italian dialects, wherein a post-tonic high vowel triggers raising of preceding mid vowels. She examined the conditions under which weak vowels trigger and control harmony.

As for the phonotactics, there is a large body of research demonstrating that phonotactics play a significant role in language processing both for children and adults. Nine-month-old infants listen longer to words that respect English phonotactics rather than those that violate them (Jusczyk, Friederici, Wessels, Svenkerud; 1993) and listen longer to words that contain high-frequency sound patterns than words with low-frequency sound patterns (Jusczyk, Luce & Charles- Luce; 1994). Infants of this age can also use phonotactic probabilities to help segment words from fluent speech (Mattys & Jusczyk; 2001).

Ohala (1993) argued that variation in perception is potential sound change, and that perceptual factors play a primary role in the shaping of the phonological patterns. Ohala (1994) addressed the role of perception in the development of VH systems, arguing that the phonological process of vowel harmony is phonologization of the phonetic process of vowel-to vowel coarticulation. Several studies, beginning with Öhman (1966), found that vowels are produced differently depending on the vowels in adjacent syllables.

Various constraint types have been proposed to account for harmony in optimality theory (OT). The assumption in OT is that harmony, like other phonological processes, is derived from the interaction of constraints that are universal and ranked differently in different languages. Alignment and agreement constraints, as well as constraints against adjacent spans of a feature, have been proposed as mechanisms to account for harmony.

As cited in Linebaugh (2007), Akinlabi (1994, 1997), Archangeli & Pulleyblank (1994b), Cole & Kisseberth (1994), Kirchner (1993), and Orie (2003) suggest that vowel harmony is accomplished via alignment constraints that require a harmonic feature be aligned with the left or right edges of a word or other morphologically defined domain. Directionality, which is generally not inherent to autosegmental approaches, is inherent in this approach; right-alignment controls progressive harmony, and left-alignment controls regressive harmony. The mechanism of 'spreading' found in autosegmental theory is also found in alignment approaches. A harmonic feature spreads to satisfy the alignment constraint. In addition to spreading, the notions of floating features and underspecification are common to alignment and autosegmental approaches to harmony.

There is no attempt here to delineate the strengths or weaknesses of the competing models. It is not a goal of this dissertation to make a comparison between various phonological models of vowel harmony. On the contrary, I wish to draw attention to the similarities shared by these approaches. In each case, whether achieved through alignment, agreement, span theory, or spreading of a feature in autosegmental theory, vowel harmony is a phonotactic constraint that creates a feature-based dependency between two or more segments. Segments within the harmonic domain must share a feature specification. The expectation is that different features would be treated equivalently because these theories do not implicate feature structure, feature classes, or feature values at all. Any feature can harmonize, and there is no prediction that a vowel height-based dependency would be different in any fundamental way from a vowel backness-based dependency. Thus, there is no prediction that vowel height harmony systems should differ typologically in any fundamental way from vowel backness harmony systems. The question of whether such typological differences exist and whether any such differences can be tied to phonetic factors thought to shape vowel harmony systems is the focus of this dissertation.

Linebaugh (2007) studied different vowel harmony systems and found the common patterns and differences between languages having backness harmony and height harmony. He also did a small experiment on English and Spanish speaking subjects to highlight the differences between these two systems. His stimuli consisted of nonsense CVCV words inserted into the phrase '_____ la _____'. The words he used either had backness (B) or height (H) harmony. There were also some words which were defined as disharmonic. His analysis suggested that back harmony facilitates speech production in some way that height harmony does not. He claimed that evidence for this indication is found when he compare error rates on back harmonic forms to error rates on height harmonic forms and B&H disharmonic forms as a combined group. In this comparison, in which back harmonic forms were set against all forms that are back disharmonic, he saw fewer errors on back harmonic forms than on the combined forms. For back harmonic forms, the mean error rate on 36 trials was 3.0 errors at an error rate of 8.2%. On the combined 72 trials for height harmonic forms and B & H disharmonic forms, the mean error rate was 3.8 errors at an error rate of 10.6%. In addition, again in terms of percentages, 13 of 20 subjects had a lower error rate on back harmonic forms than on the combined group, while 5 subjects had a higher error rate on the back harmonic forms, and 2 performed equivalently on the two types. This comparison showed that subjects overall produced errors at a lower rate on back harmonic forms than on forms that were back disharmonic.

However, he found no significant difference in error rates on height harmonic forms and B&H disharmonic forms. Given that the error rate on back harmonic forms was lower than the error rate on height harmonic forms, it was no surprise that there was no significant difference when comparing error rates on height harmonic forms to error rates on back harmonic and disharmonic forms combined. Thus there was no statistically significant evidence that subjects made fewer errors on height harmonic forms than on forms that were height disharmonic.

In Linebaugh (2007)'s study, speed was another factor to determine the ease of production. There were no statistically significant findings when comparing average syllable counts on harmonic forms and disharmonic forms. Subjects overall were neither faster nor slower in the production of harmonic versus disharmonic forms. However, error rates on back harmonic forms were found to be significantly lower than error rates on disharmonic forms, and the lower error rate was consistent across all three consonants.

He reported that these findings provide evidence that back harmonic forms are in some way easier to produce than disharmonic forms. He also noted a further evidence of a facilitative effect of back harmony on speech production when the error rate on back harmonic forms is compared to the average error rate on all back disharmonic forms. Height harmonic and disharmonic forms combined represent the back disharmonic set, and a significantly lower error rate was found when comparing subject performance on back harmonic forms to performance on that combined back disharmonic set.

To sum up, his study provided evidence that vowel backness harmony (VBH) facilitated speech production, but no such facilitative effect is found for vowel height harmony (VHH). He reported that (2007: 60): 'The divergent findings concerning the two types of vowel harmony lead to the conclusion that the facilitative effect is not attributable to economy in speech planning at the phonological level. If recycling of abstract phonological features in the planning of successive chunks of speech were responsible for the benefit to speech production, I [Linebaugh] expect that recycling of the height feature would provide the same advantage as the recycling of the backness feature. This is not the case; there is a clear advantage in producing back harmonic forms that does not carry through to the production of height harmonic forms except when the consonant is /t/, where there are fewer errors on height harmonic forms compared to B&H disharmonic forms.'

Linebaugh (2007: 61) also noted that 'the back harmonic forms are also harmonic with respect to rounding. It is possible that the ability to recycle two features, backness and rounding, offers a benefit that recycling only one feature, height, does not.' However, in a study of Korean speakers, Oh & Cole (2006) found that a facilitative affect for back harmonic sequences was not dependent on the number of features shared. In an experiment utilizing the same experimental design and same task as the one described in Linebaugh (2007), they found a significant facilitative effect for back harmony, but not for height harmony, even though both back and height harmonic forms were harmonic with respect to roundness. In this case the asymmetry between findings for back harmonic forms and height harmonic forms cannot be attributed to the sharing of two feature values as opposed to sharing one feature value. It appears that back harmony provides a benefit that is not found for height harmony. Thus, the conclusion that the facilitative effect is not likely attributable to economy in phonological speech planning is supported.

Linebaugh (2007) also provided a detailed analysis and comparison of languages with backness and height harmony. Vowel backness harmony (VBH) is most well known as a feature of Altaic and Uralic languages. This type of harmony and roundindg harmony is attested in almost all languages in this language family: Tatar (Poppe, 1963; Poppe, 1965), Xakas (Anderson, 1998), Nogai (Poppe, 1965), Kumyk, Karačay, East Turki (Poppe, 1965), Kyrgyz, Tyvan, Bashkir (Poppe, 1964), Chagatay, Yakut, Azerbaijan, Mongolian and Tungusic. Linebaugh also states that VBH is found in Uralic languages. Finnish and Hungarian are the best known languages in the Uralic family. VBH is not found as consistently within Uralic languages as in Altaic languages. The presence or lack of VBH is not predictable based on the group or subgroup that a language belongs to. For example, within the Balto-Finnic subgroup, Finnish has VBH , but Estonian and Livonian do not. Within the Ugric subgroup, Hungarian has VBH, but Vogul does not. Within the Northern Samoyed subgroup, Selkup has VBH, but Enets does not. The basic principles of VBH in Uralic are consistent with what is seen in Altaic.

Within a given word, there are only front vowels or only back vowels, and for these purposes, a word is defined as a stem and its suffixes. There are, however, some important differences. First, in almost all Uralic languages that have VBH, the front unround vowels *i* and *e* are neutral and co-occur with both front and back vowels. Second, RH is not as common as in Altaic. RH is found in Hungarian (Collinder, 1965), Kamass, and Selkup (Collinder, 1965). These languages have been in close contact with Turkic languages, and it is likely that RH is attributable to Turkic influence (Collinder, 1965). What might be termed canonical VBH in Uralic is VBH that is unaccompanied by RH and where the front unround vowels are neutral. Finnish is representative of this type of harmony. VBH has developed outside of the Altaic and Uralic language groups in at least four languages: Kera, Tunica, Macuxi, and Wikchamni.

As for vowel height harmony (VHH), Linebaugh states that the language family most often associated with VHH is the Bantu family, since most Bantu languages exhibit some type of VHH. He divides Bantu languages two major groups with respect to VHH. In the first group, VHH lowers affix vowels under the influence of a mid stem vowel. This harmony generally operates in a left-to-right direction. The second group is characterized by VHH that operates in a right-to-left direction raising mid vowels under the influence of a high vowel. Membership in the two groups is not mutually exclusive; there are languages that exhibit both types of harmony. Some Bantu languages he lists having the property VHH are: Nyamwezi, Lega, Holoholo, Nande, Kikuyu, Sukuma, Rimi, Kinga, Nyakyusa, Matumbi, S. Kongo, Mongo, Nkundo, Mituku, Gusii, Kuria, Beembe, Vili, Laadi, and Mbundu. Hyman (1999) cites Mbunda, Kwangali, Kwezo, Dciriku, and Pende as examples. VHH is found in a number of Romance language dialects. VHH is found in a number of Romance language dialects. It is found in the Montañes Spanish dialects of Pasiego and Tudanca. The Italian dialect Servigliano, also exhibits VHH. In addition, VHH applies optionally in Brazilian Portuguese. VHH is found in at least four Romance languages: Pasiego Spanish, Tudanca Spanish, Sevigliano Italian, and Brazilian Portuguese. The vowel system of one dialect Old Norwegian, a Germanic language spoken from about 1050 to 1370, exhibits VHH. The Celtic language Breton has VH that affects only mid vowels. Chamorro, an Austronesian language spoken in Guam, exhibits height harmony under certain circumstances. C'Lela, a Benue-Congo language spoken in Nigeria, evinces VHH in both roots and across root-suffix boundaries. Menomini, a member of the Algonquian family of languages, has regressive height harmony.

After examining different languages with VBH and VHH, Linebaugh (2007) makes a comparison between the two types of harmony. One of the most obvious differences is that there are many more varieties of VHH than VBH. Within Bantu alone, the language family that most consistently exhibits VHH, there are many varieties of VHH. In some cases, VHH applies in a left-to-right direction, in other cases a right-to-left direction. In some Bantu languages, only lowering occurs. In other languages, only raising occurs. In a few languages both lowering and raising occur. In many languages, the low vowel does not participate either as a trigger or as a target. There are, however, languages where the low vowel is a trigger for lowering and other languages where it is a target of raising. In the majority of languages that have lowering VHH, there is asymmetry with respect to harmonic effects on front vowels versus back vowels. In other languages, there is no asymmetry; VHH operates the same with respect to front and back vowels. In some languages, prefixes harmonize, and in others they do not. In some languages, the final vowel harmonizes, and in others it does not. In some languages, there is complete assimilation wherein after harmony has applied, the trigger and target vowels are the same height. In other languages, assimilation is partial. Target vowels change height, moving towards the height of the trigger vowel but do not reach the same height as the trigger. It is clear that there are numerous varieties of VHH within Bantu languages alone.

Linebaugh (2007) also reports that there is much less variety in the way VBH operates in Uralic and Altaic (UA), the two language families that most consistently exhibit VBH. In these languages, the basic principles underlying harmony are consistent across almost all languages in the two families. There is a co-occurrence restriction that prevents back vowels and front vowels from occurring in the same word. In all of these languages, the domain in which that restriction applies is the same: a stem and its suffixes. Variation in the operation of VBH in Altaic and Uralic languages is limited to whether or not there are neutral vowels and whether or not VBH is accompanied by rounding harmony. When the analysis is extended to VBH that exists outside of the Altaic and Uralic families, however, the difference between VBH and VHH with respect to variety is not so evident. There is great variety in how VBH operates in these languages. In general, VBH in these languages is much more restricted than is the case in Uralic and Altaic, and the restrictions are different in each language. In part, the variety that is evident in non Uralic-Altaic languages is possible because in these languages, VBH operates on only a subset of the vowels. Linebaugh (2007: 221) argues that when all of the vowels participate in harmony, as is the case in Uralic and Altaic VBH, the opportunities for variety are limited. It is worth noting that in two of the non Uralic-Altaic languages, it is only central vowels that are affected by VBH. He condired this as a hint as to one reason why the variety found in VHH is not as common in VBH. There are at least three distinctive vowel heights in all Bantu languages. In Uralic and Altaic languages, where harmony is along the front-back dimension, there is only the front and back distinction.

Linebaugh (2007: 222) lists the characteristics shared by VHH and VBH in non-Uralic and Altaic languages as:
1. Harmony is the dominant-recessive type.
2. Only a subset of vowels participates.
3. There are contextual limitations.
4. The domain of harmony is generally not the phonological word.

VHH almost always operates on only a subset of the vowels. In many Bantu languages, as well as in many non-Bantu languages, the low vowel is non-participatory. In a few cases, the high vowel does not participate. Such is the case in vowel raising in Bakweri, where a high vowel is neither a target nor a trigger. High vowels are also non-participatory in VHH in Daur. In VBH in Altaic Uralic languages, on the other hand, all the vowels participate in harmony. The only exception is Eastern Cheremis, where only word final mid vowels are affected.

Linebaugh (2007) claims that there are few characteristics common to VHH and VBH in Uralic Altaic languages. In both cases, there is a phonotactic constraint that creates a dependency between vowels, but beyond that, there is little in common. The characteristics that differentiate VHH and UA VBH, on the other hand, are overwhelmingly obvious. Uralic-Altaic VBH is pervasive and robust. All vowels participate in harmony and each vowel can be a trigger of harmony as well as a target of harmony. There are few contextual limitations on the operation of harmony, and the domain of harmony is usually the entire phonological word. VHH is a much more constrained and less robust type of harmony. Only a subset of vowels participates in harmony, and it is extremely rare that the vowels that do participate are both triggers and targets. VHH is often constrained by morphological considerations. For example, a vowel in a suffix might trigger harmony on a root vowel, but the same vowel in a root does not trigger harmony on a prefix vowel or a suffix vowel. Likewise, a root vowel might trigger harmony on a suffix vowel, but the same vowel in a suffix does not trigger harmony on a root vowel or a suffix vowel that is further to the right. In Uralic-Altaic, the domain of harmony is the entire word. That is seldom the case in VHH.

Among languages of the world, VHH is actually more common. There is some evidence for this. VHH is found in the Bantu family, four Romance languages, and nine other languages (Breton, Tibetan, Chamorro, Gilyak, C'Lela, Daur, Kera, Menomini, and a dialect of Old Norwegian). VBH is found in Uralic and Altaic languages and four other languages (Kera, Tunica, Macuxi, and Wikchamni). Based on these numbers, it appears that VHH may have arisen in more instances than VBH. It is also worth noting that the robust type of VBH found in Uralic and Altaic languages may have arisen only once. If Uralic and Altaic languages are genetically related, VBH might be attributable to a common proto-language. It is not clear, however, that the two language families are genetically related. Linebaugh (2007: 231) suggests that VBH in Uralic and Altaic is robust and pervasive because the phonetic variation that leads to VBH is robust and pervasive. VHH is less robust and pervasive because the phonetic variation that leads to VHH is sporadic and limited.

Given the significant and obvious differences between VHH and VBH in Uralic-Altaic, Linebaugh (2007: 232) concludes that the two types of harmony are too disparate to be considered a unified phenomenon. They are fundamentally different processes. The common description of vowel harmony as a process where vowels within a specified domain (usually the word) share a feature is descriptive of Uralic Altaic VBH, but it is inaccurate as a description of VHH.

2.2. Studies on Vowel Harmony in Turkish

The studies on Turkish vowel harmony conducted to date are mostly descriptive and theoretical. The first study on vowel harmony in Turkish is by Lees (1961, cited in Crothers & Shibatani, 1980) which defined vowel harmony as a progressive assimilation rule. The first vowel of stems is fully specified for all features, including harmonic features of palatality and labiality and the remaining vowels are archiphonemes. Lees (1966) provided a list of words as '*sabun, pamuk, kabuk, havuz, hamur, davul, çabuk'* and claimed that the labial consonant in between the two vowels is the reason for the rounded vowel in the second syllable. He noted that there are only a few exceptions to labial attraction harmony[3], citing three examples: *kamış, sabır, tavır*. Lewis (1967:15) also provided a description of vowel harmony as 'If the first vowel of a word is a back vowel, any subsequent vowel is also a back vowel; if the first vowel is a front vowel, any subsequent vowel is also a front vowel.'

The first psycholinguistic experiments on vowel harmony in Turkish were conducted by Zimmer (1969), who tested the validity of labial attraction by conducting two experiments. In the first experiment, he provided pairs of CVCVC nonsense words to Turkish native speakers where the two words differed only in the identity of the second vowel. Then, he asked the speakers which of the two words in each pair sounded more likely to be a potential Turkish word. In this way, he tested for the effect of vowel harmony, by comparing forms obeying vowel harmony with forms that violated it, as well as effects of labial attraction by pairing forms obeying labial attraction (as *tamuz, tafuz, tapuz, tavuz, tabuz*) with forms that violate it (*takız , tatız*). What he did in the experiment was to provide these words in pairs such as *pamuz- pamız, tafız- tafuz, tapuz- tapız, tatız- tatuz, mavız- mavuz, tabuz- tabız, takuz- takız* and then ask the subject to choose one word from each pair that might be a potential Turkish word. Zimmer's analysis lead to two conclusions: first, there was a clear difference in the effects of vowel harmony versus in the effects of labial attraction on people's preferences. Vowel harmony had a statistically significant effect: subjects consistently

[3] *It should also be noted that labial attraction does not apply to suffixes, being strictly limited to roots: cam-ım *cam-um.*

preferred forms obeying vowel harmony over those violating it. However, when it came to labial attraction there was no statistically significant difference in the preferences of subjects. The second and more unexpected result that came out of Zimmer's experiments was that some Turkish speakers preferred /a...u/ sequence over the /a....ı/ sequence with a statistically significant degree, and the place of articulation of the intervening consonant did not seem to have any effect on this choice. This suggested that labial attraction might be a part of a larger generalization; however, labial attraction itself was not the one and only right generalization. What Zimmer concluded was that there was no evidence for speakers having internalized the rule of labial attraction as a morpheme structure condition, contrary to the finding of Lees (1961).

Another crucial study in vowel harmony is conducted by Yavaş (1980). The position Yavaş (1980) proposed assigns the pivotal role to consonants rather than to vowels in Turkish consonant clusters. He showed that Turkish speakers apply VH rules to epenthetic vowels in nonsense words and to suffix vowels in foreign words. He suggested that the phonological structure of Turkish has been considerably influenced by borrowed items. He claimed that the backness of the velars was the determining factor for the backness of the consonants. In his study, Yavaş mostly focused on the factors affecting the harmonic/disharmonic properties of the choice of the epenthetic vowel in consonant clusters in Turkish. He looked into the consonantal influence on the epenthetic high vowels and reached the conclusion that when a high vowel is preceded by a velar or a lateral the backness of the vowel is determined by the backness of the velar or lateral. He noted that this diametrically oppose to the general conception of consonant harmony in which the palatality or the velarity of consonants is conditioned by the frontness or backness of the following vowel.

Crothers and Shibatani (1980: 63) defined vowel harmony as 'a co-occurrence restriction on vowel features in successive syllables'. They opposed the analysis proposed by Anderson (1969) in which front vowels are taken as the basic suffix vowels. They suggested that derivation of a word is similar to the output of a syntactic component that is a word is put together from a fully specified stem and various suffixes with vowels in archiphonemic representation. According to their view, the blank feature in the archiphonemes were interpreted as variables ranging over the values [-] or [+]. A particular choice for a certain variable in any context is checked against surface phonetic constraints to see if it's allowable there or not. Since the surface phonetic constraints only permit one value for the vowel features [palatal] or [labial] in any fully specified context, and since every word had a stem with fully specified vowels, the procedure determines the harmonic features of all vowels. Crothers and Shibatani (1980: 79) suggested that 'since alternating suffix vowels are given archiphonemic representation, it is not necessary to arbitrarily select one out of several equally marked vowels as basic, as in Kiparsky's analysis.' Later, some linguists challenged the traditional view of vowel harmony applying to all roots. These include Vago (1973), Anderson (1974) and Clements & Sezer (1982).

Clements and Sezer (1982: 250) studied vowel harmony with particular reference to disharmony in roots and suffixes and they offered evidence that apparent exceptions to vowel harmony should be treated in terms of opaque segments, a category provided by autosegmental representation. They challenged the generalizations on the labial attraction rule by observing two types of positive exceptions to Labial Attraction, i.e. sequences of /a...u/ which are not attributable to Lees' original formulation of Labial Attraction. They cited examples such as '*kılavuz, palamut, arnavut, firavun, salapurya*' where labial attraction occurs but non-initially and in polysyllabic roots. Moreover, Clements and Sezer (1982) observed a number of /a....u/ sequences which lack an intervening labial consonant, contrary to the labial attraction rule. The examples they provided were words such as '*acur, acuze, aşure, fasulya, kanun, hatun, jaluzi, mahkum, malup, marul, panjur, yahudi, yakut*', where the existence of a round vowel in the second syllable cannot be explained by labial attraction since there was no labial consonant preceding the round vowel. They also pointed out to negative exceptions to labial attraction where the existence of a labial consonant does not trigger a round vowel as in '*apış, apışmak, çapkın, çarmıh, damıtmak, hafiza, kabız, kaplıca, kızamık, münafık, muhafiz, mutabık, sapık, sarmısak, yapışmak*'. Clements and Sezer (1982) also highlighted the existence of roots with final consonant clusters (CVCC) in Turkish to show that it is rounding harmony not labial attraction that leads to the choice of the epenthetic vowel to break the consonant cluster. If it was the labial attraction, then the outcome would be an epenthetic vowel *filum* for *film* not *filim*. The correct derivation *filim* shows that the roundness property of the first vowel in the word affects the choice of the epenthetic vowel. To sum up, they demonstrated that opaque segments are categorized in Turkish as non-undergoers, blockers and spreaders with respect to vowel harmony; in this respect they differ from true neutral segments (such as consonants), which are non-undergoers but neither blockers nor spreaders. That is, they do not undergo vowel harmony, they block the spread of rounding harmony and they spread their own value onto the following vowels.

Sezer & Wetzels (1986) focused on the theoretical implications of a type of VH attested in Hungarian (e, o, ö) and Uygur (i, u, ü). They claimed that one type of vowel harmony (roundness or backness) feeds into the other type and therefore the assumption of autosegmental phonology that backness and roundness harmony are independent from one another must be abandoned. They rather advanced the claim that languages involving both rounding and backness harmony may order one type of harmony process with respect to the other, particularly where one harmonic value has a constraining effect on the other type of harmonic value. They suggested that what is implicit in this ordering requirement is the prediction that such ordering between backness and rounding harmony is always uni-directional for a given language; that is, some value of backness may determine the value of rounding or vice versa, but not both.

Balım & Seegmiller (1990) demonstrated that the claim that vowel harmony does not apply to Turkish roots was too strong and they showed that Turkish roots were indeed subject to harmonic processes. They (1990:20) made a differentiation between root and suffix harmony and they claimed that whereas suffix harmony was obligatory (operating from left to right and affecting all the relevant features of the vowels that undergo it); root harmony was optional (may operate in either direction, and may affect only one of the relevant features). Another difference between root and suffix harmony they pointed out was that in root harmony a high vowel may agree in only one of the features back and round. However, for suffix harmony, a high vowel must agree in both backness and rounding with the preceding vowel; whereas a non-high vowel must agree only in backness with the vowel to its left. They claimed that some of the disharmonic roots became harmonic in time, which is a counterevidence to what Clements and Sezer (1982) propose. The instability of disharmonic roots in Turkish was taken as evidence that vowel harmony applies within roots. They claimed that, otherwise, there would be no explanation for the changes that some roots undergo. The reason they provided for the stability of some nonharmonic roots is ‘the incentive for speakers of the borrowing language to reproduce the pronunciation of a borrowed word as closely as possible to the original, especially when the word is a learned borrowing from a language with high prestige. Since many borrowings in Turkish come from Arabic, Persian, French and English and since these languages enjoy a great prestige in Turkey, it is not surprising that many disharmonic words from these languages have shown little or no tendency to undergo changes which would make them harmonic, because speakers of Turkish can show their familiarity with these prestige languages by pronouncing the words in the original’ (Balım & Seegmiller, 1990: 11).

Sezer (1998) worked on vowel harmony in Anatolian Greek Dialects, aiming to answer the question whether VH may end or arise by borrowings from another language. He reported that Standard Ozbek lost vowel harmony as a result of heavy Iranian influence. It is also proposed by Sezer (1998) that some dialects of Armenian involve both palatal and labial harmony. Although VH is not very persistent in Anatolian Greek Dialects, as Dawkins (1916:129) notes ‘it must always be remembered that obedience to the Turkish system of vowel harmony is rather a tendency than a law.’ The borrowing, though demonstrates the fact that VH can indeed pass from one language to another through language contact. However, it should be noted that the term vowel harmony is not used in its full sense since the rule is not borrowed and applied to all the lexicon of the language; however, there are cases where VH applies to even disharmonic words in Turkish (such as Turkish *kenar –> kener*). Sezer concluded that it is possible for a language to develop or lose VH by borrowing vowel harmony. As Sezer (1998:54) puts it ‘.... it (vowel harmony) may spread from one language to another to cover words or suffixes that are not cognates.’

Charette & Göksel (1997), following their 1996 analysis of Turkic languages, claimed that vowel harmony processes in certain Turkic languages can be derived from a set of licencing constraints which also underlie the vocalic inventory of these languages. They analyzed vowel harmony from the perspective of Government Phonology and suggested (1997:1) that harmony is 'an instantiation of an element licencing itself in a position it governs.' Their proposal was that the phonetic make-up of the languages and the harmony phenomenon can be explained by the same principles. Their definition of VH includes the spreading of an element from a governing nucleus into nuclei it governs (1996:42) and define spreading as an instance of element-licencing. That is, an element X occurring within a governing nucleus licences the presence of this element X (i.e. licencing itself) into the expression of the nuclei it governs. They further argue that Turkic languages have unrestricted backness (I-harmony) but differ with respect to rounding (U-harmony). This follows jointly from the absence of a licencing constraint on the element I, one requiring the element U to be the head of a phonological expression and the availability of role-switching in the language. A licencing constraint preventing the element A to licence an operator within a phonological expression also explains the absence of A harmony in Turkic languages. They (1997:19) propose that harmony is 'an instantiation of element-licencing' and conclude that 'licencing constraints not only determine the vocalic inventory but also explain how vowel harmony operates'.

Later, Hacıoğlu (1994) pointed out the problems with generative and autosegmental approaches in detail. She proposed that the descriptions of vowel harmony put forward within generative and autosegmental phonology were inadequate and argued that vowel harmony can simply be accounted for within a more general type of rule, precisely that of the process of metaphony. She adopted the definition of Anderson (1980:3, cited in Hacıoğlu, 1994:303) for metaphony as 'the quality of a vowel is dependent on that of a neighbouring syllable.' Hacıoğlu put forward that VH is simply an instance of an ordinary process, metaphony, and need not be treated in such a complex way, as within generative and autosegmental phonology, especially for a language like Turkish. She takes the existence of examples such as 'okuldakiler' where the vowel of the suffix –DA agrees with the vowel on its left despite the fact that it agrees in between two conflicting vowels, to support the case for progressive rule of palatal harmony in Turkish.

In a potential counterargument to a link between VCV coarticulation and vowel harmony, Beddor & Yavuz (1995) found that patterns of VCV coarticulation in Turkish did not parallel the process of vowel backness harmony in Turkish. They did not conclude, however, that this mismatch means there is no cause-and effect relationship between VCV coarticulation and vowel harmony. Vowel harmony is active in Turkish and is generally described as a left-to-right process. There is, however, a large number of words that do not participate in harmony, and Beddor & Yavuz (1995) found that anticipatory, or right-to-left, coarticulation, in these disharmonic roots is much more prevalent than carry-over, or left-to-right, coarticulation. Thus, the phonetic process of VCV coarticulation is reverse from the phonological pattern of vowel harmony. The authors, however, rejected the idea that these findings should cause us to dismiss the likelihood that vowel harmony is historically linked to VCV coarticulation. They argued that we should not expect a phonological phenomenon that is historically linked to phonetic behavior to track changes in that phonetic behavior. Changes in segment inventories, changes in prosodic structure, and other changes to phonological structure may lead to changes in VCV coarticulation. It is not expected that the historically linked phenomenon of vowel harmony would also be affected. It is also not clear that vowel backness harmony (VBH) in Turkish is always left-to-right. Clements & Sezer (1982) suggested that VBH in Turkish is bidirectional. Bakovic also (2000) claimed that vowel harmony in general is bidirectional, and that the apparent directionality of harmony in languages such as Turkish is due to the lack of prefixes in the language.

Polgárdi (1999) also worked on vowel harmony in Turkish. She claims that vowel harmony is no longer very active in roots in Turkish. That is, there are many disharmonic roots. She lists the following examples of disharmonic roots (Polgárdi, 1999: 116):

a/i *takvim, fiat*
a/e *haber, hesap*
o/i *polis, pilot*
o/e *otel, metot*
i/u *billur, muhit*
u/e *kudret, mebus*

Polgárdi also noted that the most marked vowels of the system, /ü, ö, ı/ are rare in disharmonic roots– with the exception of /i...ü/ and /ü...i/ sequences (like *düzine* and *virüs*) which do occur regularly. When such combinations appear, they are unstable and they tend to regularize. She provides the following examples for this (Polgárdi, 1999: 116):

ü~i *komünist ~ kominist*

ö~e *mersörize ~ merserize*

ü~u *püro ~ puro*

u~ü *nüzul ~ nüzül , kupür ~ küpür*

i~ü *bisküvit ~ büsküvüt*

Inkelas et al. (2001) investigated the controversial root structure constraint in Turkish. They analyzed the database of Turkish Electronic Living Lexicon (TELL) in Turkish by three different tests: testing the strength of labial attraction in general lexicon, by testing etymological effects and by decomposing labial attraction. They also analyzed the lexicon of Old Turkic and Old Ottoman Turkish comparing them to Modern Turkish. As a result of their historical comparisons, they concluded that somewhere between Old Ottoman (which lacked rounding harmony) and Modern Turkish, rounding harmony in its present form was introduced. They claimed that various Persian and Arabic loanwords retained their original disharmonic vowel patterns since they were borrowed into the language before rounding harmony was introduced. They came to the conclusion that labial attraction is not supported statistically, there being only a minor and incomplete sound change labializing some vowels following labial consonants, which they prefer to call ‘labialization’. To sum up, their etymological and dialectal analysis does not support the application of Lees’ rule of labial attraction about the Turkish lexicon. They further claimed that labial attraction does not appear to have been true for any stage of Turkish going back as far as Old Turkic. According to their analysis, the only synchronic generalization in Standard Turkish that seems to be valid is there being a strong tendency for /u/ to be favored over /ı/ following a labial consonant.

2.3. Studies on Speech Errors and Speech Segmentation in Other Harmonic Languages

Evidence from speech errors indicates there is a distinctive feature level below the phoneme level (Sevald & Dell, 1994; Levelt, 1989). In speech errors it is often the case that one phoneme intrudes upon and replaces another phoneme, and there is a tendency for the intruding phoneme to be similar to the target with respect to distinctive features. This tendency is called the phonetic-similarity constraint in Levelt (1989). Bi-directional spreading of activation between the phoneme level and the distinctive feature level accounts for this phenomenon. An activated phoneme node spreads activation to the appropriate set of distinctive feature nodes representing voicing, nasality, place of articulation, etc. The activated feature nodes in turn spread activation to phoneme nodes that are connected to those feature nodes. For example, activation of the node for the phoneme /p/ activates nodes for the features 'stop', '-voice', and 'labial'. Activation of the 'stop' and '-voice' nodes in turn spreads and activates the node for the phoneme /k/ among others, and /k/ in a sense competes against, and sometimes replaces /p/ in the output. This explains why /k/ is much more likely than say /f/ or /l/ or /z/ to intrude upon a target /p/.

A second type of speech error in which features themselves slip is also evidence for a distinctive feature level. An example cited in Fromkin (1971) is an error in which the intended *clear blue sky* came out as *glear plue sky.* In this example, there appears to have been an exchange of the voicing features of the /k/ in *clear* and the /b/ in *blue.* Feature slips constitute a strong evidence for a feature level in the speech production model.

Shattuck- Hufnagel (1986) worked on speech errors in English natural speech. She focused on vowel errors and how they represent phonological information during speech planning. Her main question was whether distinctive features play a role in the representation of vowel segments at the level where vowel errors occur. She found that most of the speech errors with [u] include [u] being replaced by [o]. Her findings further suggest that [back] feature was the most common reason for errors. Her data suggests that word-initial vowel errors are slightly more common than non-initial. In her paper, Shattuck- Hufnagel (1986) finds that 52.94 % of the speech errors with [u] include it being replaced by [o]. 37% of the errors with [o] were because [o] was replaced by [u]. Shattuck- Hufnagel (1986) thinks that this finding is parallel to the findings with consonant errors, where it was found out that the place of articulation errors were more common than manner and voicing errors. Her data suggests that word-initial vowel errors (54%) are slightly more common than non-initial (46%).

Campbell (1986) showed that Finnish speakers apply vowel harmony rules to novel inputs in a word game. He interpreted this result as an evidence that the ability of native speakers to apply VH productively to novel forms does demonstrate that a rule (rather than, say, memorization) is at work. It does not tell us, however, what form the VH rule actually takes for speakers, or whether formal simplicity and phonetic naturalness influence that form.

The ability to recycle features activated in speech planning might explain advantages that accrue to speech planning as a result of vowel harmony. Sevald & Dell (1994) found that subjects were able to repeat CVC syllables more quickly when the whole word was repeated or when the final consonant was repeated. Residual activation of nodes is suggested as the explanation for the benefit of repetition. Nodes that have been recently used are more easily activated. In such a model, a speech plan that includes repetitions should be easier to implement than one that does not include repetitions. In a related study, Sevald et al. (1995) found that sequences of nonsense syllables were produced more quickly when the syllables shared a common syllable structure. The benefit of shared syllable structure was found irregardless of whether segmental content was shared. They attribute the facilitative effect to economy at the level of speech planning. The ability to repeat aspects of a plan makes it easier to implement the plan. Likewise, it is possible that a facilitative effect linked to vowel harmony might be attributed to recycling of features in the planning of successive chunks of speech.

Dell (1995) claimed that speech errors are an excellent source of data for understanding the nature of language and how it is produced. He presented different views on speech error studies, one being the Freudian approach and the other being the cognitive science approach. The Freudian approach claims that some unconscious intention is the reason for slips. Cognitive approach, on the other hand, says that the slips are the result of the information-processing requirements of producing a language. Slips occur because of the need for creativity at each linguistic level. Dell (1995) then went on to classify different kinds of slips, there seems to be slips at every unit of language- clause, phrase, word, morpheme, syllable, syllable part. There are slips that include substituting one word for another, some include exchanging morphemes etc. Dell divides slips into different types: anticipations, exchanges, shifts and perseverations. Anticipation errors are those that are caused by the segment following and perseverations are those caused by the segment preceding. It is not always easy to categorize slips. Dell reported some research which suggests that the most slippable units are the most basic units in language- the word (basic for syntactic level), the morpheme (basic for building up morphologically complex units) and the phoneme (basic for phonological level). Dell claimed that slips always obey a syntactic category rule. Slips always occur as a result of productivity. Sound errors are always very well behaved that is, they respect the hierarchical structure of the syllable, the vowel and consonant categories and rules that specify how sounds are put together. Dell reported that some researchers have proposed that phonological representation is constructed the same way as syntactic representation. So, there are trees with slots for each phoneme. Another interesting property of errors is that they rarely occur in short, common words such as functional lexicon. The reason Dell provideed for this fact is that function words do not need much creativity to be produced. Rate also has an effect on word errors, speakers make more mistakes with phonemes when compared to words and the reason is the need to produce more phonemes than words.

Sofu (2001) worked on speech errors in Turkish during natural language production. She adopted Fromkin (1971)'s categorization of speech errors: 1. shift and exchange, 2. perseveration, 3. anticipation, 4. deletion, 5. addition, 6. substitution and 7. blend. She pointed out that Turkish speech errors follow the patterns outlined by Garrett (cited in Carroll, 1985) in that: 1. The initial phonological units are more likely to switch places with other initial segments. 2. Vowels tend to switch place with vowels and consonants with other consonants. 3. Even if a word that is not a part of the language's lexicon is created as a result of speech errors, that word still conforms to the phonological rules of the language in question. 4. Stress is systematic in speech errors. It can be observed from her findings that Turkish speakers preserved vowel harmony even in their speech errors, as can be seen from her data: *benim*-----> *banım*, *tırıl tırıl* (as a combination of *tiril tiril* and *pırıl pırıl*).

Another line of research focused on the relationship between vowel harmony and slips of the tongue. Niemi and Laine (1997) found that palatal harmony in Finnish is persistent in slips as well as language games. Their claim was that slips of tongue offer a direct window to mental grammar since they are spontaneous and subconscious output errors. Such errors indicate a temporary breakdown in language production but they are still non-random in that they follow the ways the system is organized. As far as vowel harmony is concerned, their experiments indicated that all movement and blend errors that could potentially create vowel harmony violation are produced correctly. They concluded that those slips verified the fact that vowel harmony has an "accommodatory nature" in language.

There have been many studies in Finnish vowel harmony and the advantages it provides for speech segmentation. All the research in Finnish shows that vowel harmony helps speakers to segment words (Suomi, McQueen and Cutler, 1997; Vroomen, Tuomainen and Gelder, 1998). Such research mostly focused on how vowel harmony aids adult speakers with segmenting words. Those studies only focus on speech segmentation showing that disharmony signals word boundaries and thus help speakers to segment words.

The study by Suomi et al. (1997) was the first to actually show that Finnish speakers employ vowel harmony as a useful cue for speech segmentation. Their hypothesis was that a harmony mismatch between two syllables containing vowels from different harmony classes signals a word boundary. To test this they had five experiments. Finnish only has the palatal (front-back) harmony. There are 3 front, 3 back and 2 neutral vowels. Harmonically neutral vowels can be combined with vowels from both harmonic classes but two harmony classes do not occur with one another. Harmony propagates from left to right and from root to suffixes. In the first experiment, they tested whether harmony will help subjects with word segmentation. Listeners were given trisyllabic nonsense strings, some of which ended with embedded disyllabic words. Some of these trisyllabic strings were such that all vowels in the string belong to the same harmony class and with some other strings the vowel in the initial syllable is disharmonious with the rest. The hypothesis was that vowel harmony helps speech segmentation speakers will find it easier to spot target words in disharmonious strings when compared to harmonious strings. Their results were significant and they showed that people were faster in words with disharmony. The effect was larger for words with front harmony than for words with back harmony. Their results for this experiment clearly suggested that disharmony can be used to help segmentation in word onset in Finnish.

In the second experiment, Suomi et al. (1997) wanted to test whether disharmony also helps segmentation at word offsets. This time they asked speakers to spot bisyllabic target words at the beginning of trisyllabic nonsense strings. Their hypothesis was that a harmony mismatch at the offset of a word can be used to assist in recognition of that word and word-spotting performance should be easier in disharmonious strings. Their results revealed no harmony effect, targets were detected equally fast and correct in both harmonious and disharmonious strings. Responses to front harmony words were somewhat faster than those to back harmony words, but this difference was not significant. These results showed that harmony information acts as a cue only when it marks word onset. In the third experiment, target words occured either at the beginning or at the end. Their hypothesis this time was that since subjects were not going to focus on initial or final position, harmony then harmony mismatch effects should be found for the final-position targets only and not for the initial-position targets. The results showed that there was a great effect of harmony. The effect was large on final position targets, where the subjects were much faster in responding to targets in disharmonious strings than to targets in harmonious strings. The targets with frontness harmony were also significantly larger. As for the initial-position, there were no reliable effects in the error rate analysis. The finding from this experiment was that disharmonious information cues word boundaries, but this segmentation cue only assists in the recognition of words following such a boundary not preceding. Experiment 4 explored the front/ back interaction further. The authors replicated the first experiment in that they told the subjects to spot the words which are finally embedded in nonsense items. The results indicated that harmony effect was larger for targets with front vowels than for targets with back vowels. Front vowel targets were spotted more accurately in disharmonious strings when compared to harmonious strings. In experiment five, the subjects were asked to detect a real word in a list of words and non-words to see if it is only disharmony that gave the previous results. Their hypothesis was that there is some acoustic feature of words in disharmonious contexts that made them easier to detect in lexical decision task than those in harmonious contexts. The results showed that targets that appeared in harmonious contexts were detected no more or less rapidly than those in disharmonious contexts. Front harmony words were detected more rapidly than back harmony words. These results suggested that the harmony effects found in the third and fourth experiment were due to harmonious or disharmonious contexts in which the target words were presented and not due to any acoustic differences between targets from different contexts. These results also showed that word stress did not have an important role in recognition of Finnish speech.

All five experiments they did showed that vowel harmony mismatch is a useful cue to listeners in on-line processing of speech in that it facilitates detection of the beginning of a new word. Their conclusion supports their hypothesis in that vowel harmony functions as a segmentation cue.

Vroomen et al. (1998) conducted a similar study to look at the effect of vowel harmony in speech segmentation. In the first experiment, they replicated the experiment conducted by Suomi et al (1997). The task of the subjects was to detect a bisyllabic CVCV word which was preceded by either a harmonious or disharmonious prefix. The results showed that Finns were much faster at detecting words which have a disharmonious prefix. There was no effect of target words with vowels from the front or back harmony class. They showed that Finns use a mismatch in vowel harmony as a cue to tell word boundaries. In the second experiment, they investigated whether word stress plays a role in speech segmentation and whether vowel harmony effect remains the same when the onset of the target word is stressed. Their hypothesis was that if Finnish speakers use stress as a cue in word segmentation then the items with stress should be easier to detect than those without. They did not make any prediction about vowel harmony. The results showed that there was no effect of vowel harmony and no difference between targets with front and back harmony classes. There was also no difference between harmonious or disharmonious items. They found out that words with a stress cue had a much faster reaction time and a much smaller harmony effect than words without a harmony cue. The results of this experiment showed that stress was a more powerful cue than vowel harmony for Finnish speakers. In the third experiment, Finnish, Dutch and French speakers were asked to segment an artificial language. Their results showed that Fins profited from vowel harmony and word initial stress, Dutch profited from word-initial stress and French did not profit from either of these. These results indicated that vowel harmony and word-initial stress are language specific properties. Stress seemed to be the strongest cue for Finnish speakers to segment words and stress reduces the effect of vowel harmony.

2.4. Studies on Artificial Language Learning

Vitevitch and Luce (1999) found faster processing for nonwords with high compared to low phonotactic probability in a speeded same-different judgement task. In other words, subjects responded faster to items that were similar to the phonotactics of their language. In a similar study, Vitevitch, Armbrüster and Chu (2004) reported that words with high phonotactic probability were produced more quickly in a picture naming task. There is also evidence that nonwords with high phonotactic probability are retained better in short term memory compared to nonwords with low phonotactic probability (Gathercole, Pickering, Hall & Peaker, 1999; Majerus, Linden, Mulder, Meulemans & Peters, 2004). Pylkkanen, Stringfellow & Marantz (2002) proposed a different timecourse of brain activity for listening to words with high versus low phonotactic probability. Speakers were more likely to make speech errors that change a low probability combination of sounds into a high probability combination rather than vice versa (Motley & Baars, 1984). It was also found that in general speakers rarely produce speech errors that violate the phonotactic constraints of their native language (Fromkin, 1971), that is even the speech errors follow the sound patterns of the language spoken. Onishi, Chambers & Fisher (2002) have demonstrated that simply hearing stimuli that embody a novel phonotactic constraint was adequate to tune the processing mechanisms of listeners.

Dell et al. (2000) showed that speech production errors follow the phonotactic rules of the language that is being spoken. That is, even though people make speech errors the errors still conform the phonology of the language. He suggested that people can learn new phonotactic constraints as adults, simply by exposure to patterns in the words they produce. They had three different experiments where they asked the participants to recite CVC syllables in 4 sessions on different days. In Experiment 1, some consonants were always onsets and some were always codas and some were used as both onsets and codas. [h] was always an onset and [η] was always a coda, complying with English phonotactics. A speech error with either of these sounds will be a test for language-wide phonotactic constraints. The sounds [f] and [s] were confined to syllable position throughout all four experiments. An error in either of these sounds will be a violation of experiment-wide phonotactic constraints. The subjects were asked to repeat four-syllable sequences (such as "feng kem hem nes") in time with a metronome. The subjects made many speech errors while repeating sequences in time with a metronome; however their errors still obeyed the coda- onset constraints. All the errors lead to possible sound sequences in the language, in that the subjects never created a speech error where [η] was used as word onset since they never saw it in that position. In the second experiment, some sounds were restricted to a particular position whereas the others were not. The findings showed that subjects were aware of this constraint since they did not make many mistakes on those sounds that were restricted. The results showed that the subjects were implicitly learning some generalization or rule about the set of possible onsets or possible codas. In the third experiment, possible vowel and consonant onsets depended on vowel identity. It suggests that the experiment-wide error effect can be sensitive to consonant position-vowel combinations.

All the experiments supported the claim that there is an implicit learning. The processing system learns by experiencing sound sequences and storing them in the memory. These three experiments showed that speech errors reflect a speaker's knowledge of where sounds occur in syllables and words. Errors obey language-wide phonotactic constraints, so all the errors lead to possible sound sequences in the language. The results support breath of constraint hypothesis which claims that patterns in language occur at many levels of generality and the processing system is sensitive to all these levels. With respect to learning, the data suggests implicit and rapid learning. There is also an effect of recent experience, that is recently experienced sound forms are more accessible. The authors came to the conclusion that the learning mechanism has three properties: it is sensitive to recent experience, it is implicit and it is capable of generalization. That is, even though people make speech errors the errors still conform to the phonology of the language.

Phycha et al. (2003) investigated the roles of formal simplicity and phonetic naturalness in the learning of a vowel harmony pattern. For this purpose, in the artificial language experiment they designed, they asked speakers speaking a non-harmonic language to learn different patterns of non-local vowel interaction by listening to nonce forms in the laboratory. Their aim was to determine whether listeners exhibit better learning with phonological patterns that are phonetically natural versus those that are phonetically unnatural. Their definition for "phonetically natural," include (Phycha et al., 2003: 424) a pattern which could conceivably arise from listeners' interpreting the acoustic cues of speech at face value – that is, interpreting them without reference to any grammar. In the experiment they conducted each word consisted of a CVC stem followed by a VC suffix whose vowel alternated according to the vowel of the stem. Subjects listened to pairs of stem and suffixed forms exhibiting a particular pattern, and were then asked to make judgments about novel pairs of stem and suffixed forms. They took correct judgments as an indication of learning. To accomplish the goal of measuring learnability by varying formal simplicity and phonetic naturalness, they devised two different experimental conditions, (a-b) and a control condition, (c). In these conditions the value of the feature [back] in the stem vowel predicts the value of that same feature in the suffix vowel. No further information was needed.

a. *Palatal Vowel Harmony* (VH): stem and suffix V agree in [back]
b. *Palatal Vowel Disharmony* (DH): stem and suffix V disagree in [back]
c. *Palatal Arbitrary* (ARB): stem and suffix V may agree or disagree in [back], depending upon what the stem V is.

In the experiment, the subjects were told that they were listening to singular-plural pairs in a new language, and that their task was to learn how to make plurals in this language. The procedure consisted of three parts: a listening session, a learning session with feedback, and a testing session with no feedback. The goal of the listening session was simply to expose subjects to correct singular-plural pairs. The results showed that subjects did significantly better learning in the Harmony and Disharmony conditions when compared with subjects in the Arbitrary condition. The authors interpreted this result as evidence that the presence of feature predictability played a role in learning. Subjects in the Harmony condition exhibited significantly better learning than those in the Arbitrary condition. Likewise, subjects in the Disharmony condition exhibited significantly better learning than those in the Arbitrary condition. On the other hand, phonetic naturalness did not appear to play a role in learning. Subjects in the Harmony and Disharmony conditions did not produce significantly different results from one another. They concluded that their experiment confirmed (Phycha et al., 2003: 433) 'the Simplicity Hypothesis by showing that naïve listeners learned phonological processes that exhibited single-feature predictability significantly better than those processes that did not.' The experiment did not, however, confirm the Naturalness Hypothesis since the subjects did not learn a phonetically natural process significantly better than a phonetically unnatural one. They thus reached the conclusion that, given brief exposure to nonce forms in laboratory conditions, harmony and disharmony appear to be equivalently learnable patterns. This finding suggested that phonetically natural processes are *not* more 'cognitively accessible' to listeners than unnatural ones. It further suggests that phonetic factors may not have a privileged role to play in a synchronic grammar. They finally address the question of why harmony patterns are more widely attested than disharmony patterns cross-linguistically since their study only suggested that predictable processes (that is, predictable based on a single feature) were more cognitively accessible than non-predictable ones.

Koo (2007) made experimental study using computational models to investigate whether adult speakers can learn non-adjacent phonotactic constraints, and how their perception and grammaticality judgment behavior change as a result of learning. Her experiments test learnability of four constraints on non-adjacent phonemes that hold in the final two syllables of CV.CV.CV nonsense words: liquid harmony, liquid disharmony, backness harmony, and backness disharmony. These four phonotactic constraints govern non-adjacent phonemes in that the two constrained positions are one phoneme apart from each other. As stated by Koo (2007:21) 'For liquid harmony and disharmony, the constrained positions are the last two syllable onsets separated by an intervening vowel. For backness harmony and disharmony, the constrained positions are the last two nuclei, or vowels, separated by an intervening consonant.'

As a result of the experiments Koo (2007) showed that evidence of learning was found for both liquid harmony and backness harmony. Moreover, the two constraints were learned equally well. Subjects showed discriminability between legal and illegal words for both liquid harmony and backness harmony. Koo (2007:41-42) interpreted these results as showing that 'the adult phonological processing system can not only learn second order phonotactic constraints contingent on the adjacent vowel but also the constraints contingent on a non-adjacent phoneme.

His results indicated that adults can learn phonotactic constraints that are nonexistent in their language and which restrict co-occurrence of two non-adjacent phonemes with one intervening phoneme. The results further document evidence of the malleability of the adult phonological processing system, and extend the range of learnable sound patterns since non-adjacent phonological dependencies are assumed to be difficult to learn. As a result of learning, Koo asserts that the speakers judge phonotactically legal novel words to be more grammatical than phonotactically illegal novel words. They also perceive the legal ones more quickly and accurately than the illegal ones. In addition, the experiments showed that the effect of learning on perception is greater when the learned phonotactic constraint restricts co-occurrence of more confusable phonemes. Koo interpreted this subtle effect of learning on perception as the Perceptual Facilitation Hypothesis, which provides a more detailed account of how the phonotactic knowledge functions in the adult phonological processing system to change its perceptual behavior. The experimental results were simulated with two computational models that demonstrate how the adult phonological processing system adapts to recent experience: how it comes to perceive legal sound sequences better than illegal ones after repeatedly processing sequences embodying non-adjacent phonotactic constraints, and how it learns the constraints from observing the perceptual output and computes the probability of the perceived phonological structure in judging its grammaticality. The models suggest possible mechanisms that underlie the adaptation of the adult phonological processing system and guide the direction of future research by providing falsifiable predictions.

CHAPTER 3

ANALYSIS AND DISCUSSION

In order to receive adequate exposure to the intended constraint, it was important that participants produce the target words accurately most of the time. Thus, participants who produce errors on more than 50% of the occurances of any of the four vowels were excluded from all analysis (n = 1). Data from the remaining participants were analyzed for evidence of learning vowel harmony constraints based on two measures: performance on the forced choice test and the pattern of speech errors produced. In addition to the results of the test phase and the analysis of speech errors, the words subjects remembered were also studied to see whether there is a learning effect of the condition each subject was trained on. First, the results of speech errors will be presented.

3.1. ANALYSIS AND DISCUSSION FOR SPEECH ERRORS

The speech errors subjects made were transcribed by the experimenter. In order to avoid any possible errors, two native speakers of Turkish also transcribed 80% of the recordings. Furthermore, to avoid any bias that can be caused by the phonology of Turkish, 40% of the tapes were also transcribed by a Polish speaker.

The tapes were not acoustically analyzed. The tapes with the recordings of the subjects were listened to by the experimenter and anything that sounded different than the actual item was noted. The errors for each subject were noted this way and then the type of errors were categorized.

The errors are provided in two ways: 1. The number of errors (consonant, vowel, switch errors) 2. The rate of errors (which shows the average number of errors for each subject). The speech errors were analyzed according to the categories provided by Fromkin (1971). Fromkin categorized speech errors as: 1. shift and exchange, 2. perseveration, 3. anticipation, 4. deletion, 5. addition, 6. substitution, 7. blend.

3.1.1. Backness Harmony Errors

3.1.1.1. Speech Errors of Harmony Subjects trained in Backness Harmony Condition

Harmony subjects trained in the backness condition saw two vowels that agreed in their backness feature, and also their rounding feature as a result of the nature of the four vowels used in the experiment. As discussed in the first chapter, the errors for harmony subjects trained in the backness harmony condition were categorized as:

1. Consonant errors (which shows the error rate)
   Switching the order of consonants, repeating the first consonant etc.
   ex: fi**b**e --> fi**f**e
   The number of consonants not pronounced will also be provided under deletion.
2. Errors in the vowels:
   a. Keeping the first vowel and replacing the second vowel with it (perseveration)
      ex: f**o**bu --> fob**o**
   b. Keeping the second vowel and replacing the first vowel with it (anticipation)
      ex: f**o**bu --> f**u**bu
   c. Switching the order of the two vowels within the word (exchange)
      ex: f**o**b**u** --> f**u**b**o**
   d. Creating disharmony (substitution)
      ex: fob**u** --> fob**i**

As the example (d) above illustrates, this type of speech error includes one of the four vowels used in the experiment but the properties of the vowel clashes with the properties of the vowel in the item and the result is disharmonic.

   e. Substituting another vowel that is not one of the four vowels (o, u, e, i) used (other vowel errors)
      ex: f**o**bu --> f**a**bu

3.1.1.1.1. Possible Speech Errors

Before giving the list of actual speech errors the subjects made in the experiment, the list of possible errors will be provided. The reason for this is to show the wide range of possible errors so that these can be later compared with the actual errors. This in turn will facilitate observing the patterns in the actual errors. Here is a list of all the possible errors they could have made:

1. ***Repeating first vowel (perseveration, identity):*** This includes taking the first vowel and replacing it with the second vowel in the item with the first vowel, thus creating two identical vowels in the word. It should be noted that, this is not a violation of vowel harmony. On the other hand, it is an example of creating an extreme vowel harmony where vowels agree in all features in that they are identical.

o-u → o-o (fobu → fobo)

u-o → u-u (fubo → fubu)

e-i → e-e (febi → febe)

i-e → i-i (fibe → fibi)

2. ***Repeating the second vowel (anticipation, identity):*** This includes taking the second vowel and replacing it with the first vowel in the item, thus creating two identical vowels in the word. It should be noted that, this is not a violation of vowel harmony either. On the contrary, it is an example of creating an extreme vowel harmony where vowels agree in all features in that they are identical.

o-u → u-u (fobu → fubu)

u-o → o-o (fubo → fobo)

e-i → i-i (febi → fibi)

i-e → e-e (febi → febe)

3. ***Switching vowels (exchange):*** This is achieved by switching the order of the two vowels in the item, so that what used to be the second vowel gets to be the first vowel in the new item created and what used to be the first vowel becomes the second vowel. Again, it should be noted that there is not a violation of vowel harmony in this speech

error; since the vowels are the same and the combination of the vowels are the same; it is only the order that is changed.

o-u → u-o (fobu → fubo)

u- o → o-u (fubo → fobu)

e-i → i-e (febi → fibe)

i-e → e-i (fibe → febi)

4. ***Another vowel (substitution):*** This case is the example where vowel harmony may be violated. This is the case when one of the vowels in the word is replaced with another vowel used in the experiment. However, the vowel chosen is one of the four vowels used in the experiment. But since the vowel used does not agree with the backness/ frontness or rounding features of the other vowel in the item the result would be disharmonic.

o-u → o- e (fobu → fobe)

o-u → e- o (fobu → febo)

o-u → o-i (fobu → fobi)

o-u → i-o (fobu → fibo)

o-u → e-u (fobu → febu)

o-u → u-e (fobu → fube)

o-u → i-u (fobu → fibu)

o-u → u-i (fobu → fubi)

u-o → u- e (fubo → fube)

u-o → e- u (fubo → febu)

u- o → u-i (fubo →fubi)

u- o → i-u (fubo →fibu)

u-o → e-o (fubo → febo)

u-o → o-e (fubo → fobe)

u-o → i-o (fubo →fibo)

u-o → o-i (fubo →fobi)

e-i → o-i (febi → fobi)

e-i → i-o (febi → fibo)

e-i → u-i (febi → fubi)

e-i → i-u (febi → fibu)

e-i → e-o (febi → febo)

e-i → o-e (febi → fobe)

e-i → e- u (febi→ febu)

e-i → u- e (febi→ fube)

i-e → i-o (febi→ fibo)

i-e → o-i (febi→ fobi)

i-e → i-u (febi→ fibu)

i-e → u-i (febi→ fubi)

i-e → o-e (fibe → fobe)

i-e → e-o (fibe → febo)

i-e → u-e (fibe → fube)

i-e → e-u (fibe → febu)

This list illustrates all the possible errors in this set.

5. ***Another vowel not used in the experiment:*** This is another example of vowel harmony being violated. Only the vowels [e], [i] and [o], [u] were used in the experiment. Insertion of a vowel that is not one of these four vowels will result in disharmony in terms of the system. Insertion of [ı], [ö], [ü] or [a] will all result in disharmony when the rules of the artificial language are considered. Only the possible list of errors with o-u in the target item are given below:

o-u → o- a (fobu → foba)

o-u → a- o (fobu → fabo)

o-u → o-ü (fobu → fobü)

o-u → ü-o (fobu → fübo)

o-u → o- ı (fobu → fobı)

o-u → ı- o (fobu → fıbo)

o-u → o-ö (fobu → fobö)

o-u → ö-o (fobu → föbo)

o-u → a-u (fobu → fabu)

o-u → u-a (fobu → fuba)

o-u → ı-u (fobu → fıbu)

o-u → u-ı (fobu → fubı)

o-u → ü-u (fobu → fübu)

o-u → u-ü (fobu → fubü)

o-u → ö-u (fobu → föbu)

o-u → u-ö (fobu → fubö)

6. Consonant errors: Consonant errors include switching the place of the consonants, changing the voicing of the consonant, changing the place of articulation feature of the consonant, changing the manner of articulation feature of the consonant, not pronouncing some consonants, creating identical consonants by copying the first or the second consonant. When consonant errors were counted only changes in consonants were noted, changes in the vowels fall into one of the previous categories. Here are just a few possible examples of consonant errors, the list does not exhaust all the possible errors:

g → b (gobu → bobu)

d → t (pide → pite)

v → g (vogu → gogu)

g → v (govu → vovu)

b → ∅ (pebi → pe)

f → v (febi → vebi)

s → z (sozu → zozu)

v → f (vibe → fibe)

t → g (tudo → tugo)

t → b (tive → tibe)

s → z (sodu → zodu)

3.1.1.1.2. Actual Participant Errors

After giving the list of all possible errors, now the actual errors the subjects produced will be provided. As can be observed from the following table 4 and 5, subjects did not exhaust all the possible errors they could have done. Rather, their errors tend to fall into certain categories.

3.1.1.1.2.1. Vowel errors

Table 4 provides the errors on the first column along with the category of the errors. So, [o]-[u] stands for a word with [o]-[u] sequence such as *fobu*. Thus, o-u → o-o, illustrates *fobu* being pronounced as *fobo* as a result of speech error. The second column represents the total number of errors in that type, which was calculated by adding the number of subjects who conducted that same error. The third column provides the rate of speech errors, that is the number of errors divided by the number of subjects.

Table 4: The list of speech errors in vowels of subjects trained in harmony condition of backness harmony

Vowel errors	**Total number**	**Rate**
Repeat 1st V (perseveration)	0	0
Repeat 2nd V (anticipation)		
o-u → u-u	2	0.16
Switch Vs **(exchange)**		
o-u → u-o	7	0.58
u- o → o-u	6	0.5
i-e → e-I	1	0.083
e-i → i-e	1	0.083
Other vowel errors	0	0
Another vowel	0	0
Disharmony		
u-o → u-e	1	0.083

As can be observed from table 4 above, some errors were more common than others. If we compare these actual errors to the list of all possible errors, we see that the speech errors of subjects tend to fall into certain categories. To illustrate, there were no examples of speech errors where the first vowel was replaced by the second vowel and there were only two examples where the second vowel was replaced by the first vowel, and all the replacements of the first vowel included [o] being replaced by [u]. The most common error was the [o]-[u] string in a word being replaced by [u]-[o], by switching the order. Some of the examples to this error are: *vozu* being pronounced as *vuzo*, *pogu* being pronounced as *pugo*. The second most common speech error was [u]-[o] replaced by [o]-[u], as in the example *pudo* being pronounced as *podu*. Subjects also made switching errors where [e] and [i] were switched, however these were less common. There was only one case where [e] was replaced by [i] and one example where [i] was replaced by [e]. Such speech errors do not yield to disharmony since it is still the same vowels but the only thing that changes is the order. It has been noted in the previous literature that this type of error is a very common mistake attested with consonants as well (Dell et al., 2000).

An analysis of errors of the subjects trained on backness harmony condition reveal that subjects made more errors with the round vowels. It should be reminded at this point that all back vowels used in the experiment were also round. The errors of subjects in this condition were in one of the three categories: switching errors, disharmony errors and repeating the first vowel.

When switching errors are analyzed, it is observed that there was a total of 13 switching errors with the back rounded vowels compared to that of 2 switching errors with the unrounded front vowels [e] and [i]. There was only one instance where a vowel was replaced by another vowel and created disharmony. In that case the sequence [u]- [o] was replaced by [u]-[e], thus [o] was replaced by [e]. What is interesting in this error is that a change in two features is needed to go from [o] to [e]. The subject changed the rounding and backness features of the original vowel, and thus created disharmony. However, the height feature remains unchanged since both [o] and [e] are low vowels. The other speech error where the first vowel was repeated is also interesting since when the original vowel [o] was replaced it was not replaced by a very different vowel but it was replaced by a vowel in which two out of three features are shared. When [o] was replaced by [u] backness and rounding features remains the same. Only height feature is changed since [u] is a high vowel.

3.1.1.1.2.2. Consonant Errors

As can be seen from table 5 below, subjects trained in backness harmony made a total of 149 consonant errors. They made much more consonant errors when compared to their vowel errors. The total number of vowel errors was 18.

Table 5: The list of speech errors in consonants of subjects trained in harmony condition of backness harmony

Consonant errors	**Total number**	**Rate**
f → p	2	0.16
f → v	4	0.33
s → z	6	0.5
s → f	3	0.25
v → b	2	0.16
v → f	6	0.5
v → g	5	0.41
v → z	10	0.83
t → p	1	0.083
t → f	1	0.083
d → g	12	1
d → b	8	0.66
d → f	1	0.083
d → s	1	0.083
d → v	2	0.16

d → t	5	0.41
g → d	6	0.5
g → b	7	0.58
g → v	4	0.33
g → f	1	0.083
g → k	1	0.083
g → z	2	0.16
b → d	10	0.83
b → p	11	0.91
b → f	1	0.083
b → g	1	0.083
b → v	4	0.33
k → t	1	0.083
k → g	1	0.083
k → p	1	0.083
p → b	1	0.083
p → t	2	0.16
p → d	1	0.083
p → k	1	0.083
p → f	7	0.58
p → g	1	0.083
z → v	5	0.41
z → d	3	0.25
z → f	1	0.083
z → s	5	0.41
z →g	1	0.083

There were 42 different types of consonant errors and a total of 149 errors. The most common consonant error was replacing [d] with [g], a total of 12 times. The next most common consonant error in this group was replacing [b] with [p], which occurred a total of 11 times. The other most common consonant error was replacing [b] with [d], and [v] with [z] both occurring a total of 10 times. This is followed by replacing [d] with [b], which occurred 8 times in the data of backness disharmony subjects. After that, the next most common mistake was replacing [g] with [b] and [p] with [f], each of which occurred 7 times. Then replacing [s] with [z], [v] with [f] and [g] with [d] follow, which all occurred 6 times each. Replacing [d] with [t] and [z] with [v] occured a total of 5 times in the data. All other consonant errors occurred less than 4 times.

An analysis of the properties of consonant errors indicates certain patterns. It was observed that although consonants were replaced by other consonants as a result of speech errors, still some features as voicing, place or manner of articulation were kept constant in the errors.

a) Errors with plosives:

When [b] was included in a speech error it was replaced by either of these five consonants: [d], [g], [p], [v] or [z]. When the phonetic properties of [b] is compared with the other five consonants it was replaced with, it is observed that [b] shares the voicing feature with four of the five consonants. Both [b] and [d], [g], [v] and [z] share the feature of being voiced. We can thus say that in most of the errors, the place of the glottis is not changed in this kind of speech error by participants. When the error of [b] being replaced by [p] is analyzed, it can be observed that only one feature is changed to make [b] into [p], that is voicing. Both [b] and [p] are bilabial plosives and the only feature that distinguishes them is [b] being voiced and [p] being voiceless. It is seen from the speech error that the subject did not change the place and point of articulation features of the consonant but only changed the voicing feature. It is also worth noting that the features [+consonantal], [-syllabic] are shared between [b] and all the consonants it was replaced with, that is [d], [g], [p], [v] and [z]. Except for [g] all the consonants it was replaced with share the [b]'s feature of being [-back]. Except for [z] all other substitutions for [b] share [b]'s original feature of being [-distributed].

It is worth noting that the same pattern of error was observed with the consonant [d]. In the experiment, [d] was replaced by four other consonants: [g], [t], [v] and [z]. It can easily be observed that the same pattern is at stake here. Three of the four errors by the participants did not change the voicing feature. There was only one error where they changed the voicing feature but kept the other two features unaltered. That is, in the speech errors the subjects made, [d] was replaced by [g], [v] and [z]. Thus, the feature of voicing was not altered. On the other hand, in the speech error where [d] was replaced by [t] all the place and point of articulation features of [d] was constant and only the voicing feature was changed, resulting in the voiceless dental plosive [t] instead of its voiced counterpart [d]. It should be noted here that changing [d] to [t] was slightly more common than the other three errors since the same type of error was conducted by two different subjects. Again, except for the substitution of [d] by [g], the feature of being [-back] is shared among other substitution errors since [z], [t] and [v] are also defined as non-back consonants.

The most varied set of substituted consonants for harmony subjects trained in backness harmony was observed with the voiced velar plosive [g]. There were 6 different consonants that were replaced by [g] as a result of speech errors. Four of these consonants ([b], [d], [v] and [z]) share the feature of being voiced as is the case with [g]. On the other hand, [k] and [p] have the opposite feature of voicing when compared to [g]. [g] and [k] only differ in terms of voicing since they are both velar stops. [g] and [p], [b] and [d] also share a common feature in that they are all stops although, [p] and [b] are bilabial stops and [d] is a denti-alveolar stop. Replacing [g] with [z], was the error where the most type of features were changed, since [z] is a voiced denti-alveolar fricative and [g] is a voiced velar stop, the only feature they share is voicing. So, both place of articulation and manner of articulation were changed in this type of error. It is also worth noting at this point that this error was one of the most common errors, with an instance of 4. The other most common error was replacing [g] with [v], where another change of two features were required. [g] and [v] share the feature of voicing but they differ in point and manner of articulation features.

The velar voiceless stop [k] was replaced by either [t], [g] or [p]. The nature of these errors are very interesting, since replacing [k] with [g] requires only changing one feature (voicing). Replacing [k] with [t] or [p] also requires changing one single feature but this time point of articulation. [k] and both [t] and [p] share the features of being an oral stop and being voiceless.

An analysis of the errors with [p] reveals that the sounds it was replaced with were more varied compared to the errors with [k] and [s]. When [p] was replaced by another consonant it was one of [k], [b], [t], [d], [g] and [f]. Although the set seems to be wide and diverse, it is yet not difficult to see the common properties shared by these consonants. First of all, all of these consonants except [f] share the feature of being an oral stop. Secondly, [p] and [b] share all the features except the voicing feature, since [p] is voiceless but [b] is voiced. Also, [p], [b], [t], [d] and [f] all share the common property of being anterior consonants. Last but not least, [p], [t] and [f] share the feature of being voiceless. At this point, it should be noted that replacing [p] with [f] was the most common error with 7 occurrences, the other types of errors occurring in only 1 or 2 instances.

The only error with [t] was it's being replaced by [p] or [f]. [t] and [p] share the feature of being oral stops and being voiceless. [t] and [f], on the other hand have the common feature of being voiceless and being anterior consonants but they differ in manner of articulation since [t] is a denti-alveolar stop and [f] is a labio-dental stop.

b) Errors with fricatives

When the errors with the voiceless labio-dental fricative [f] were analyzed, it was realized that [f] was replaced by [b], [d] or [v]. It should also be noted that replacing [f] with [v] was slightly more common than other errors which were only conducted by one subject, whereas this particular one was conducted by two subjects. It should be noted that all the speech errors related to [f] required it's voicing features to be altered, since both [b], [d] and [v] are voiceless whereas [f] is not. Changing [f] into [b] and [d] also require manner and place of articulation features to be changed. However, replacing [f] with [v] does not require any modification in those features since [f] and [v] already have the same manner and place of articulation features.

When the errors with [s] were analyzed in detail it occurred that [s] participated in speech error 9 times. Although this number suggests the fact that it was a common speech error, it was remarkable to note that all these errors include [s] being replaced by either [v] and [z]. As [s] is a denti-alveolar voiceless fricative, it's being replaced by [z] requires only a change in voicing. It's being replaced by [v], however, requires a change both in the place of articulation and state of the glottis since [v] is a voiced labio-dental fricative.

The speech errors with [v] included it's being replaced by either [b], [f], [g] or [z]. Except [f], all other consonants share the feature of being voiced; and [f] shares all other features with [v] except voicing. All the errors except [g] have the common feature of being anterior consonants as [b] is bilabial and [f] and [z] are labio-dental and denti-alveolar, respectively. The error that required the most number of features to be changed was the change from [v] to [g] since they only shared property of being anterior.

The errors with [z] can be said to be much more varied when compared with that of [t]. When [z] participated in a speech error, it was replaced by one of the following six consonants: [g], [s], [v], [d], [f]. An analysis of these errors revealed that there were again some common properties between the properties of the original consonant and those of the consonant it was replaced with. To begin with, [z], [s], [f], [v] and [d] share the feature of being anterior consonants. Furthermore, [z] and [v], [d], [g] share the feature of voicing, since they are all voiced consonants. Being a fricative, [z] also shares the manner of articulation feature with [s], [v] and [f]. The error where the original vowel [z] is most similar to the vowel it was replaced with in terms of properties is the error where it was replaced by [s]. [z] and [s] share all the manner and place of articulation features (both being denti-alveolar fricatives) yet differ in the place of glottis feature when they are pronounced.

A detailed analysis of the consonant and vowel errors suggested the conclusion that subjects kept many features similar, even though they made a speech error by replacing the original vowel or consonant sounds with new ones. This analysis supports the previous analysis conducted on speech errors both in natural languages (Fromkin, 1971; Sofu, 2001) and those in artificial languages (Dell, 1995). It seems that Turkish subjects make use of the same principles with subjects speaking a natural language. What this suggests in a broader framework is that the errors in an artificial language such as the one used in this particular experiment are parallel to the errors in a natural language.

The following table 6 gives a summary of all the speech errors described by classifying errors in to borader categories.

Table 6: Distribution of speech errors for harmony subjects trained in backness harmony

Consonant Errors	149
Consonant deletion	25
Vowel substitution (perseveration + anticipation)	1
Vowel exchange	16
Other Vowel Errors	0
Creating Disharmony	1
Vowel deletion	25
TOTAL NUMBER OF ERRORS	217

As can be observed from table 6 above, the speech errors of subjects trained in backness harmony condition still adhered to vowel harmony. That is, even if subjects made speech errors they kept vowel harmony in their errors. There is only one example out of all the 217 speech errors that violated vowel harmony. The fact that no other vowel were inserted other than the four vowels used in the experiment and that only one of the speech errors resulted in disharmony illustrate that subjects learnt the rules of the artificial language they were presented with and even kept it in their speech errors.

The number of consonant errors was used to assess the error rate. This was compared to consonant errors to those subjects trained in disharmony and mixed condition to see which condition was more difficult for Turkish subjects.

3.1.1.2. Speech Errors of Disharmony Subjects trained in Backness Harmony Condition

In the disharmony condition, subjects were presented with strings where each word had two vowels and the vowels differed in backness/frontness and rounding features. That is if a word had a back/round vowel in the first syllable it had a front non-back/non-round vowel in the second syllable, and vice versa. Some of the words presented to subjects were *vizo* and *gezu* where the vowels differed for these features mentioned.

As has been discussed in the first chapter, the errors for disharmony subjects will be categorized as:

1. Consonant errors (which show the error rate)
   Switching the order of consonants, repeating the first consonant etc.
2. Errors in the vowels:
   a. Keeping the first vowel and replacing the second vowel with it (perseveration)
      ex: zegu → zugu
   b. Keeping the second vowel and replacing the first vowel with it (anticipation)
      Ex: bido → bodo
   c. Switching the order of the two vowels within the word (exchange)
      ex: sedu → sude
      vizo → vozi
   d. Changing the phonetic properties of both vowels
      ex: buve → bevo
      fivo → fuve
   e. Creating harmony (by changing the phonetic properties of the vowels)

ex: guze → gize

pube → pubo

f. Substituting another vowel that is not one of the four vowels used

ex: figo → fügo

3.1.1.2.1. Possible Speech Errors

Table 2 displays the properties of the speech errors in detail. Before, presenting the real speech errors, a list of all the possible errors the subjetcs could have made is provided so that a comparison with the actual errors can be made. Possible errors can be presented as:

1. ***Repeating first vowel (perseveration, identity):*** This includes taking the first vowel and replacing the second vowel in the item with the first vowel, thus creating two identical vowels in the word. It should be noted that, this is not a violation of vowel harmony. On the contrary, it is an example of creating an extreme vowel harmony where vowels agree in all features since they are identical.

e-u → e-e (febu → febe)

u-e → u-u (fube → fubu)

o-i → o-o (fobi → fobo)

i-o → i-i (fibo → fibi)

2. ***Repeating the second vowel (anticipation, identity):*** This includes taking the second vowel and replacing the first vowel in the item, thus creating two identical vowels in the word. It should be noted that, this is not a violation of vowel harmony either. On the contrary, it is an example of creating an extreme vowel harmony where vowels agree in all features since they are identical.

o-i → i-i (fobi → fibi)

i-o → o-o (fibo → fobo)

e-u → u-u (febu → fubu)

u-e → e-e (fube → febe)

3. ***Switching vowels (exchange):*** This is achieved by switching the order of the two vowels in the item, so that the second vowel of the word becomes the first vowel of the new item, and the first vowel becomes the second vowel. Again, it should be noted that there is not a violation of vowel harmony in this speech error; since the vowels and the combination of the vowels are the same. It is only the order that is changed.

o-i → i-o (fobi → fibo)

u- e → e-u (fube → febu)

e-u → u-e (febu → fube)

i-o → o-i (fibo → fobi)

4. ***Another vowel (substitution):*** This case is the example where vowel harmony may be violated. This kind of error occurs when subjects replace one of the vowels in the word with another vowel used in the experiment. However, the vowel the subject uses is still one of the four vowels used in the experiment. But since the vowel used does not agree with the backness/ frontness or rounding features of the other vowel in the item the result is disharmonic. The possible changes are:

o-i → o-e (fobi → fobe)

o-i → e-o (fobi → febo)

o-i → e-u (fobi → febu)

o-i → u-e (fobi → fube)

o-i → i-u (fobi → fibu)

o-i → u-i (fobi → fubi)

i-o → o-e (fibo → fobe)

i-o → e-o (fibo → febo)

i-o → e-u (fibo → febu)

i-o → u-e (fibo → fube)

i-o → i-u (fibo → fibu)

i-o → u-i (fibo → fubi)

e-u → o-e (febu → fobe)

e-u → e-o (febu → febo)

e-u → i-o (febu → fibo)

e-u → o-i (febu → fobi)

e-u → i-u (febu → fibu)

u-e → u-i (fube → fubi)

u-e → o-e (fube → fobe)

u-e → e-o (fube → febo)

u-e → i-o (fube → fibo)

u-e → o-i (fube → fobi)

u-e → i-u (fube → fibu)

u-e → u-i (fube → fubi)

This list illustrates all the possible errors in this set.

5. ***Another vowel not used in the experiment:*** This is another example of vowel harmony being violated. Only the vowels [e], [i] and [o], [u] were used in the experiment. Insertion of a vowel that is not one of these four vowels will result in disharmony in terms of the system, since that vowel will not agree in the backness/frontness or rounding features of the other vowel in the word. Insertion of [ı], [ö], [ü] or [a] will all result in disharmony when the rules of the artificial language are considered. Only the possible list of errors with o-i in the target item are given below:

o-i → o- a (fobi → foba)

o-i→ a- o (fobi → fabo)

o-i → o-ü (fobi → fobü)

o-i → o-ü (fobi → fübo)

o-i → o- ı (fobi → fobı)

o-i → ı- o (fobi → fıbo)

o-i → o-ö (fobi → fobö)

o-i → ö-o (fobi → föbo)

o-i → a-u (fobi → fabu)

o-i → u-a (fobi → fuba)

o-i → ı-u (fobi → fıbu)

o-i → u-ı (fobi → fubı)

o-i → ü-u (fobi → fübu)

o-i → u-ü (fobi → fubü)

o-i → ö-u (fobi → föbu)

o-i → u-ö (fobi → fubö)

6. Consonant errors: Consonant errors include switching the place of the consonants, changing the voicing of the consonant, changing the place of articulation feature of the consonant, changing the manner of articulation feature of the consonant, not pronouncing some consonants, creating identical consonants by copying the first or the second consonant. When consonant errors were counted only changes in consonants were noted, changes in the vowels fall into one of the previous categories. Here are just a few possible examples of consonant errors; the list does not exhaust all the possible errors:

g → b (gobi → bobi)

d → t (pido → pito)

v → g (vogi → gogi)

g → v (govi → vovi)

b → ∅ (pebu → pe)

f → v (febu → vebu)

s → z (sozi → zozi)

v → f (vebu → febu)

t → g (tude → tuge)

t → b (tivo → tibo)

s → z (sodi → zodi)

3.1.2.2.2. Actual participant errors

After giving the list of all possible errors, the actual errors the subjects produced will be provided ın the following section. As can be observed from the following tables 7 and 8, subjects did not exhaust all the possible errors they could have done. Rather, their errors tend to fall into certain categories.

3.1.1.2.2.1. Vowel errors

The following table 7 provides the errors on the first column along with the category of the errors. So, o-u stands for a word with o-u sequence such as the word *fobu*. Thus, o-i → o-o, illustrates a disharmonic item *fobi* being pronounced as *fobo* as a result of a speech error. The second column represents the total number of such errors across subjects. This was calculated by adding the number of errors of each subject from that category. The third column shows the rate of speech errors, that is the number of errors divided by the number of subjects.

Table 7: The list of speech errors in the vowels of subjects trained in disharmony condition of backness harmony

Vowel errors	**Total number**	**Rate**
Repeat 1st V (perseveration)	0	0
Repeat 2nd V (anticipation)	0	0
Switch Vs (exchange)		
o-i → i-o	1	0.083
i-o → o-i	5	0.41
e- u → u-e	4	0.33
i-e → e-i	1	0.083
e-i → i-e	1	0.083
Other vowel errors		
u-e → o-e	2	0.16
e-u → i-o	1	0.083
i-o → e-o	1	0.083
Another vowel	0	0
Creating harmony		
u-e → i-e	1	0.083

As can be seen from table 7 above, subjects trained in backness disharmony made a total of 71 consonant errors. They made much less vowel errors when compared to their consonant errors, the total number of vowel errors were 17.

When the vowel errors were analyzed in detail, it was observed that 3 of the vowel errors led to height harmonic outputs ([e]-[o] or [o]-[e] string in the same word, where the vowels agree in height). Only one of these vowel errors included creating harmony from a disharmonic item (creating [i]-[e] string from the input [u]-[e]). The other 13 vowel errors kept vowel disharmony pattern even in the vowel errors. That is, the subjects maintained disharmony even in their speech errors.

A detailed analysis of vowel errors made by subjects trained in the backness disharmony condition reveals that there are certain common properties in the errors. There was no instance of errors where the first or the second vowel was repeated, suggesting the fact that the subjects trained on disharmony condition were already aware that the two vowels in the words are very different from each other.

Switching errors were a common type of error made by these subjects. However, when these switching errors were analyzed in detail, it was observed that the high, front unrounded vowel [i] was always included in the switching errors as the first or last vowel except the [e]- [u] sequence. The other vowel used with [i] was one of the following vowels: [o], [e] or [u].

There was only one instance where harmony was created as a result of a speech error and that was when [u] was replaced by [i] in the sequence [u]- [e] leading to [i]- [e]. Since, [i] and [e] share the feature of being front and being unrounded, harmony was created.

When the errors where the original vowel was replaced by another vowel as a result of speech error during the experiment were analyzed, some common features came forward. To start with, when the vowel [u] was replaced it was replaced by [o]. This error shows that subjects changed the minimum number of features possible. [u] and [o] share both rounding and backness feature, so the only feature that was changed was height. The other replacement error was replacing [e] with [i], which again meant changing only the height feature, since both [e] and [i] are front and unround vowels. The third type of error was replacing [i] with [e], again the only modifying height feature.

3.1.1.2.2.2. Consonant Errors

As can be observed from the following table 8, backness disharmony subjects made a total of 71 consonant errors and these errors fall into 34 different types. The most common consonant error was replacing [p] with [f], which occured a total of 7 times. The next most common consonant error was replacing [v] with [b], occurring a total of 5 times. Then replacing [z] with [v], [g] with [z] and [v] with [g] follow, each of which occurred 4 times. All other consonant errors occurred less than 4 times.

Table 8: Speech errors with consonants by backness disharmony subjects

Consonant errors	**Total number**	**Rate**
b → d	1	0.083
b → g	1	0.083
b → p	1	0.083
b → v	1	0.083
b → z	1	0.083
d → g	1	0.083
d → t	2	0.16
d → v	1	0.083
d → z	1	0.083
f → b	1	0.083
f → d	1	0.083
f → v	2	0.16
g → b	2	0.16
g → d	3	0.25

g → k	1	0.083
g → p	1	0.083
g → v	4	0.33
g → z	4	0.33
k → z	1	0.083
p → b	2	0.16
p → f	7	0.58
s → v	1	0.083
s → z	4	0.44
t → k	1	0.083
v → b	6	0.5
v → d	2	0.16
v → f	1	0.083
v → g	4	0.33
v → z	2	0.25
z → d	1	0.083
z → f	1	0.083
z → g	3	0.25
z → s	1	0.083
z → v	4	0.33

An analysis of consonant errors made by backness disharmony subjects revealed that there were certain patterns in their speech errors, similar to those of harmony subjects. Backness disharmony subjects made errors with the following consonants: [b], [d], [f], [g], [k], [p], [s], [t], [v], [z].

a) Errors with plosives

The errors with the voiced bilabial oral stop [b] included it's substitution by [d], [g], [p], [v], [z]. An analysis of these errors tells that there are certain features shared with [b] and the consonants it was replaced with. To begin with, [b] and [d], [g] share two features: voicing and manner of articulation, since they are all voiced oral stops. [b] and [p], on the other hand, share all the features except voicing: that is being bilabial and being oral stop. [v] and [z] are labio-dental and denti-alveolar fricatives but they share the feature of being voiced and anterior consonants. [b] being replaced by [g] did not require the features of manner of articulation or voicing to be modified but it only meant modifying the point of articulation feature, since [b] is a bilabial voiced stop and [g] is a voiced velar stop.

When it comes to the errors with the voiced denti-alveolar plosive sound, [d], it can be observed that [d] was replaced by [g], [t], [v] or [z], the most common being with [v]. An analysis of these errors reveals that there are certain properties shared by these consonants. To illustrate, [d] and [t] share all the features except voicing, that is they are both denti-alveolar oral stops but [d] is voiced and [t] is voiceless. On the other hand, [d] and the consonants [g], [v] and [z] also have some common features. To start with, they are all voiced consonants. Except for [g], they are all anterior consonants since [d] is denti-alveolar and [v] and [z] are labio-dental and denti-alveolar, respectively.

The consonant which was replaced by the highest number of different consonants was the voiced velar plosive [g], since it was replaced by 6 different consonants being [b], [d], [k], [p], [v] and [z]. As before, there were common features among these consonants. First of all, [g] and [k] share all the features about manner of articulation and point of articulation, the only feature they differ is the voicing feature. When it comes to voicing, [b], [d], [v] and [z] all share the feature of being voiced. [b], [d], [k], [p] also share the manner of articulation feature with the original vowel [g] since they are all oral stops.

There were very few, actually one speech error with the voiceless velar stop [k] and that included a substitution with [z]. It should be noted that [k] and [z] do not share very many features in common. [k] is voiceless but [z] is voiced; [k] is velar but [z] is denti-alveolar and [k] is a stop whereas [z] is a continuant.

The speech errors with the voiceless bilabial plosive [p] included its replacement by [b] and [f]. An analysis of these errors reveals the similarities of the sounds. All three sounds are anterior consonants, either bilabial or labio-dental. [p] and [b] share all the features of manner of articulation and place of articulation, but only differ in voicing.

The errors with the voiceless denti-alveolar oral stop [t] were also very limited in number, since it only occurred in one error, when it was replaced by [k]. It should be noted here that [t] and [k] have many common features, since they are both voiceless and stops. They only differ in point of articulation since [t] is denti-alveolar and [k] is velar.

b) Errors with fricatices

Speech errors with the voiceless labio-dental fricative sound, [f], included substitution with [b], [d] and [v]. These consonants, again, share certain features. Although [f] is voiceless, all the consonants it was replaced with are voiced. They share the feature of being all anterior consonants. [f] and [v] share all features except voicing, since they are both labio-dental fricatives.

When it comes to errors with the voiced labio-dental fricative [v], we see that [v] was replaced by [b] (most common error) followed by [g], [d], [f] and [z]. To start with the error where the minimum number of features are altered, replacing [v] with [f] only requires a change in voicing. [d] and [z] are close to [v] in their place of articulation since they are denti-alveolar sounds. [v] shares the feature of voicing with [d], [g], [z], since they are all voiced.

The speech errors with the voiced denti- alveolar fricative [z] include a substitution by [d], [f], [g], [s] and [v]. There are also certain features shared among those consonants. [z] and [s] are both denti-alveolar oral stops, and they only differ in voicing. [f], [v], [s] and [z] are all dental sounds. The only feature shared by [z] and [g] is voicing.

Table 9: Distribution of speech errors for disharmony subjects trained in backness harmony

Consonant Errors	71
Consonants deleted	18
Total consonant errors	89
Vowel identity (perseveration + anticipation)	0
Vowel switch errors (exchange)	9
Another Vowel	6
Other Vowel Errors	0
Creating Harmony	1
Vowels deleted	18
TOTAL NUMBER OF ERRORS	212

As can be observed from table 9 above, the speech errors of subjects trained in backness disharmony condition still adhere to vowel disharmony. That is, even if subjects made speech errors they tended to keep vowel disharmony in their errors. The subjects did not produce any vowel identity errors, which illustrates that they were already aware of the difference of vowels. Another reason may be that, they needed to change at least two features to get identical vowels. To illustrate, if they were to pronounce *tevo* and instead say *teve*, they need to change two features of [o], backness and rounding. Also, if they made the error of pronouncing *febu* instead of *fubu*, they needed to change the backness, rounding and the height feature of the [e] to get and [u]. This may be the reason why disharmony subjects did not create many identical vowels.

There was only one example out of all the 212 speech errors that violated disvowel harmony. The fact that no other vowel were inserted other than the four vowels used in the experiment and that only one of the speech errors resulted in disharmony illustrates that subjects learnt the rules of the artificial language they were presented with and even kept it in their speech errors.

The number of consonant errors was used to assess the error rate. It seems that disharmony subjects made fewer speech errors with consonants compared to harmony subjects.

3.1.1.3. Comparison of speech errors of backness harmony and backness disharmony subjects

The comparison of speech errors made by these two different groups of subjects trained in different conditions showed that the properties of the condition they were trained on had an effect in the property of speech errors. The results indicated that harmony subjects had a higher rate of speech errors. The reason for this is that they made more consonant errors than the disharmony subjects. Whereas backness disharmony subjects made a total of 71 consonant errors, backness harmony subjects made 149 errors with consonants, which pointed out to the negative effect of the native language. Another interesting point to mention here is that the number of vowel errors by both groups was exactly the same, although the nature of the errors was distinct.

What is more crucial is that both groups adhered to the properties of the condition they were trained on whether being disharmony or harmony. The fact that subjects (except only one vowel error in each group) did not violate the condition they were trained on proves that backness harmony and disharmony was learnt by the subjects and this was even maintained in their speech errors.

A common feature in all consonant errors was that the consonant that replaced the original consonant was always a member of the set of consonants used in the experiment: [p], [b], [t], [d], [k], [g], [s], [f], [v] and [z]. That is, although subjects replaced the original consonant they saw with another consonant, the consonant was always within the set. This indicates that the subjects learned the phonetic inventory of the artificial language and they did not want to insert another consonant to the language.

Another important point to note is that the voiced or voiceless counterpart of the consonant was always included in the speech errors with consonants. This suggests that, voicing was one of the most commonly changed features in errors with consonants. This result is parallel to the study conducted on natural language speech errors in Turkish (Sofu, 2001).

These results suggest that the nature of the native language has a negative effect in the speech errors, in that harmony set (which is claimed to be much more similar to Turkish lexicon) triggered more consonant errors.

3.1.1.4. Speech Errors of Mixed Condition Subjects Trained in Backness Harmony Condition

As was mentioned in the introduction chapter under method section, mixed condition was much more complex than the other two conditions. First, it was a combination of the backness harmony and backness disharmony items, which meant that the subjects were not presented with a coherent pattern as was the case with harmony or disharmony. Since they saw both words from the harmony set and the disharmony set, there was no pattern they could generalize as the phonology of the artificial language they were presented with. However, this condition was used to see how the lack of a consistent harmony or disharmony pattern affected the subjects' speech errors and their learning the condition. This pattern can also be said to represent such languages where the language itself has a consistent choice in terms of harmony or disharmony; but, this pattern is disturbed by borrowed words which violate the pattern.

3.1.1.4.1. Possible Errors

The possible speech errors that mixed group subjects were likely to make were actually a combination of all possible harmony errors and disharmony errors presented in the previous sections, since the system they were presented with includes words from both sets. An exhaustive list of all possible errors will not be given since it is only the combination of the harmony and disharmony lists given before.

3.1.1.4.2. Actual participant errors

3.1.1.4.2.1. Vowel errors

As can be observed from the following table 10, subjects trained in the mixed condition of backness harmony made different types of vowel errors.

Table 10: The list of vowel errors of subjects trained in mixed condition of backness harmony

Vowel errors	**Total**	**Rate**
Repeat 1st V (perseveration)		
o-u -> o-o	2	0.16
Repeat 2nd V (anticipation)	0	0
Switch Vs (exchange)		
e-i -> i-e	2	0.16
u-e -> e-u	1	0.083
e-u -> u-e	1	0.083
o-u -> u-o	1	0.083
i-e -> e-i	1	0.083
Other vowel errors		
o-i -> o-e	1	0.083
i-o -> e-u	1	0.083
i-o -> u-e	1	0.083
i-o -> e-o	1	0.083
Another vowel		
u -> ü	3	0.25

Disharmony from harmony		
e-i -> e-u	3	0.25
o-u -> o-i	5	0.41
u-o -> u-e	12	1
i-e -> i-o	2	0.16
Harmony from disharmony		
u-e -> u-o	2	0.16
C errors	185	
V errors	41	
Total errors	226	

When we analyzed the vowel errors in detail, we noticed that there were only 2 instances where a speech error with vowels resulted in vowel identity. As can be seen from table 10 above, vowel identity was created from the harmony set since all the subjects' had to do to create identity from harmony was to keep one feature. That is to go to [u] from [o] the subject kept the backness and rounding features the same and changed only the height feature. There were a total of 6 vowel switch errors, 4 of them were from the harmony set and 2 from the disharmony set.

Subjects tended to create disharmony from the harmony items they saw much more than creating harmony from the disharmony items. They created a total of 22 disharmony items from harmony items. However, the total number of times they created harmony from disharmony was 4. In 2 of these instances they changed u-e string to u-o string, that is they changed only the rounding feature of the [e] to get an [o]. The other 2 times the subjects turned a disharmony item into a harmony item was when they created height harmony from disharmony. It should be noted that height harmony was not one of the conditions these subjects were presented with. However, in two instances the subjects changed o-i string to o-e and i-o string to e-o. Thus by changing [i] to [e] the result was height harmony, since in the strings o-e and e-o the vowels already agreed in height.

3.1.1.4.2.2. Consonant errors

The following table 11 provides a complete list of all the speech errors conducted by backness harmony mixed condition subjects. The total number of any error across subjects and the rate of any error can also be observed from the table.

Table 11: Speech errors with consonants by backness mixed condition subjects

Consonant errors	**Total errors**	**Rate**
b → d	3	0.25
b → k	1	0.083
b → g	3	0.25
b → p	8	0.66
b → t	1	0.083
b → v	2	0.16
d → b	2	0.16
d → g	4	0.33
d → t	1	0.083
d → z	3	0.25
f → b	1	0.083
f → k	1	0.083
f → p	1	0.083
f → v	3	0.25
g → d	5	0.41
g → k	3	0.25
g → p	1	0.083
g → v	4	0.33
g → z	2	0.16
k → g	4	0.33

p → b	4	0.33
p → f	3	0.25
p → g	1	0.083
p → k	1	0.083
s → f	1	0.083
s → p	1	0.083
s → z	5	0.41
t → f	1	0.083
t → z	1	0.083
v → b	7	0.58
v → f	5	0.41
v → g	5	0.41
v → k	1	0.083
v → z	2	0.16
z → g	1	0.083
z → s	2	0.16

When the speech errors of subjects trained in the backness harmony mixed condition were analyzed, certain patterns of errors were revealed. First of all, the most common error for most of the consonants was to change the voicing feature of the consonant, while keeping the place and manner of articulation constant. This was the most common error attested with consonants [b], [d], [f], [k], [p], [s] and [z]. Actually for [k], this was the only error attested.

a) Errors with plosives

The substitutions for the voiced bilabial plosive sound [b] were [d], [k], [g], [t] and [v]. As can be seen from the table, this was the most varied set of substituted sounds in terms of number. However, as mentioned above, the most common error was to replace [b] with [p], which occurred a total of 8 times across subjects. The next most common substitution for [b] was [d] and [g]. Changing [b] into [d] requires only the change of point of articulation. Manner of articulation and voicing features do not need to be changed, since both [b] and [d] are voiced and they are both oral plosives. The only difference is that [b] is bilabial and [d] is denti-alveolar. Switching [b] with [g] also employs the modification of the same feature, that is place of articulation. Since [g] is a voiced velar oral stop and [b] is a voiced bilabial oral stop, only the point of articulation needs to be changed to go from [b] to [g].

Changing [b] to [k], on the other hand, requires more than changing one feature. Because [b] and [k] differ not only in place of articulation but also in the state of glottis feature. Since [k] is a voiceless velar plosive, the subject had to change both the voicing and the point of articulation feature. However, it should be noted that [b] and [k] still share one feature, that is being oral stops. Replacing [b] with [t] also requires changing two features. Both the voicing feature and the point of articulation need to be changed to change [b] to [t] since [t] is a denti-alveolar voiceless stop. Changing [b] to [v] also needs a change of two features, however this time manner of articulation feature also needs to be changed since [v] is a fricative, whereas [b] is a plosive. They have the same voicing feature, but they also differ in the place of articulation feature.

When the denti-alveolar voiced plosive [d] was replaced with another sound it was one of the sounds [b], [g], [t] and [z]. The most common was [g]. Substitution of [d] with [b], requires the change of one feature only. Since both [d] and [b] are voiced plosives, the only feature they differ is the point of articulation. The sound [d] is denti-alveolar whereas, [b] is bilabial. That is, changing [d] to [b] requires fronting of the place of articulation features. The other consonant that [d] was replaced with was [g]. This replacement also needs a change in a single feature, the place of articulation feature. Since [g] is also a voiced sound and a plosive, only the point of articulation needs to be altered, [g] being velar. The articulators need to move five steps back to get to the velar sound [g]. The change between [d] and [t] is the simplest one as mentioned before, since only voicing feature is altered. [d] and [t] are both denti-alveolar sounds and they are both plosives, the only feature they differ is voicing. The final sound that [d] was replaced with was [z]. This substitution is also interesting since [d] and [z] are actually similar in two phonetic dimensions. They share voicing feature (both being voiced) and they share the point of articulation feature (both being denti-alveolar sounds). They only differ in manner of articulation since [d] is an oral plosive and [z] is a fricative.

The speech errors with the voiced velar plosive [g] included its being replaced with either [p], [v] or [z]. The most common of these was the replacement with [v], as can be observed from the table above. The easiest replacement that is between [g] and [k] did not occur, although it required only a change of the voicing feature. When the subjects used a [p] sound instead of a [g] sound as a result of speech error, two features of the original sound need to be altered since [p] and [g] differ in both voicing and point of articulation feature. [g] is a voiced velar plosive whereas [p] is a voiceless bilabial plosive. So, they only share the manner of articulation (being plosive) feature with each other. A subject who replaced [g] with [p] maintained the manner of articulation feature and changed the other two features. Replacing [g] with [v] also means the alteration of two features: manner of articulation and place of articulation feature. The only feature shared between [g] and [v] is that they are both voiced. [v] being a voiced labio-dental fricative differs from voiced velar plosive [g] in all features except voicing. Substitution of [z] for [g] required a modification of again two features. [z] and [g] only share the voicing feature. Since [z] is a voiced denti-alveolar fricative the subject had to change both the manner and the place of articulation feature of the original sound [g].

The only speech error with the voiceless velar plosive [k] included a substitution with its voiced counterpart [g], which occured a total of four times. Both being velar plosives, [k] and [g] only differ in voicing.

The voiceless bilabial plosive [p] participated in four different speech errors. It was replaced by either [b] or one of [f], [g] or [k]. The most common of these errors was the replacement with [b], occurring a total of four times. Actually, this was not only the most common error but it was also the most simple error since only one feature needs to be altered, that is the substitution of [p] by [b]. [p] is a voiceless bilabial plosive and [b] is also a bilabial plosive but [b] is voiced. In other words, the subject only changed the voicing feature to modify [p] with [b]. As for the change of [p] to [f], the subject indeed had to modify all features except the voicing feature. [p] and [f] only share voicing feature. Their point of articulation and manner of articulation features are different since [p] is a voiceless bilabial plosive and [f] is a voiceless labio-dental fricative. Another sound that [p] participated in speech error with is the voiced velar plosive [g]. The only common feature between [p] and [g] is their being oral stops. But is should be noted that [p] is a voiceless bilabial oral stop and [g] is a voiced velar oral plosive. As can be observed from their phonetic properties, they differ in terms of place of articulation and the voicing feature. The final sound in the list of consonants that [p] was substituted with is the voiceless velar plosive [k]. When compared with [g], [p] and [k] share more features since they are both voiceless and they are both plosives. However, they differ in place of articulation feature since [k], being a velar sound, is articulated further back in the mouth than [p] which is bilabial.

There were two different speech errors with the voiceless denti-alveolar plosive [t]. One of them was its being replaced by [f] and the other was by [z]. None of the subjects trained in the mixed condition of the backness harmony replaced [t] with its voiced counterpart [d]. The modification of [t] with [f] included changing both the manner and point of articulation features. Since [t] is a voiceless denti-alveolar plosive and [f] is a voiceless labio-dental fricative, the subject had to change two features of the original sound. They only share the feature of being voiceless. Modification of [t] with [z] required changing the manner of articulation feature and the voicing feature. [t] and [z] share the point of articulation feature since they are both denti-alveolar sounds. However, since [t] is a voiceless plosive and [z] is a voiced fricative they differ in these features.

b) Errors with fricatives

There were four different sounds that [f] was replaced with as a result of speech errors. These were: [b], [k], [p] and [v]. As can be observed from the table above, the most common of these errors was the one with [v]. Replacing the voiceless labio-dental fricative [f] with [b] is a speech error that needs the modification of three features of the original sound, since [f] is a voiceless labio-dental fricative and [b] is a bilabial voiced fricative. This means that the subjects had to change not only the place and manner of articulation but also the state of glottis feature susbtitute [f] by [b]. The substitution of [f] with [k], on the other hand, requires modifying two features, the place of articulation and voicing feature since [k] is a velar voiceless velar plosive. Replacing [f] with [p] also needs a change in two features: this time changing point of articulation feature one step back to bilabial and changing the manner of articulation feature to oral stop. The substitution of [f] with [v] is not only the most common speech error but also the simplest error since the subject only had to change the voicing feature. Since [f] and [v] already share the features of being fricatives and being denti-alveolar sounds only a change in voicing is sufficient.

As for the speech errors with the voiceless denti-alveolar fricative [s], they can be said to contain both similar and different sounds. [s] is a voiceless denti-alveolar fricative and it was replaced by these three sounds as a result of speech errors in the experiment: [f], [p] and [z]. Among these sounds that replaced [s], the sound with most similar phonetic properties to the original sound [s] was [z]. [s] and [z] are both denti-alveolar fricatives and the only feature they do not share is the feature of voicing. In other words, the subject who replaced [s] with [z] only modified the voicing feature. The substitution of [s] with [p], on the other hand required a change of both the manner and point of articulation feature. Since [s] is a voiceless denti-alveolar fricative and [p] is a voiceless bilabial plosive, the only common feature they have is the voicing feature. The other two features need to be modified. Using a [f] sound instead of a [s] sound as a result of speech error requires a change in only one feature since [f] and [s] share voicing (both are voiceless) and manner of articulation features (both are fricatives). A modification of solely the point of articulation feature from denti-alveolar to labio-dental is sufficient to change [f] to [s].

The speech errors with the voiced labio- dental fricative [v] were the next most varied set in terms of number after that of [b]. [v] was replaced with five different sounds as a result of speech errors during the experiment: [b], [f], [g], [k] and [z]. The second most common of these errors was the error where only voicing feature is altered, that is the error where [v] was replaced with [f]. The most common error was [v] being replaced by [b]. [v] and [b] share only the voicing feature since both of them are voiced.

However, they differ in the other two phonetic features that is manner of articulation and point of articulation. Since [v] is a voiced labio-dental fricative and [b] is a voiced bilabial plosive, they differ in two features. As was mentioned before, substitution of [v] with [f] requires a change in only one single feature, that is voicing. They already share the manner and point of articulation features. Switching [v] with [g], on the other hand, requires keeping the feature of voicing and changing all other relevant features. Since [g] is a voiced velar plosive, both the manner and point of articulation features need to be changed to go from [v] to [g]. As for the speech error, of changing [v] to [k], a change of all three features is required. Due to the fact that the voiced labio-dental fricative [v] and voiceless velar plosive [k] differ in not only voicing but also manner and place of articulation features, the subject had to change three features. The use of voiced denti-alveolar fricative [z] instead of the original voiced labio-dental fricative [v] requires only a change in the dimension of point of articulation since [z] and [v] already share the other two features.

The speech errors with the voiced denti-alveolar fricative [z] included substitution by two different sounds: [g] and [s]. The more common of these two substitutions was [s]. This was also the easier substitution when the properties of the sounds are considered since [z] and [s] share the manner and place of articulation features and only differ in terms of voicing; [z] being voiced and [s] being voiceless. The modification of [z] with [g] requires more changes in the properties of the original sound. [z] and [g] share voicing feature but they differ in terms of manner and place of articulation since [z] is a denti-alveolar fricative and [g] is a velar plosive.

The analysis of the consonants that occurred in speech errors indicated that speech errors with most of the sounds required the original sound being modified in voicing. As was noted in the literature review section, this is also a common error in natural speech (Sofu, 2001). This finding shows that the speech errors of subjects trained in the artificial language system are parallel to speech errors of subjects during natural language production. Some sounds were replaced with other sounds which differed in both voicing and manner of articulation features. Some sounds were replaced with sounds that differed in manner and place of articulation features. There was only one example (substitution of [v] with [k]) where three features were changed, in other speech errors a maximum of two features were changed. This indicates that although subjects make a speech error they use a sound that is more or less similar to the original sound.

Table 12: Distribution of speech errors for disharmony subjects trained in backness mixed condition

Consonant Errors	91
Consonants not read (deletion)	94
Total consonant errors	185
Vowel identity (perseveration + anticipation)	2
Vowel switch errors (exchange)	6
Another Vowel (substitution)	3
Other Vowel Errors	30
Total vowel errors	41
Creating harmony from disharmony	22
Creating disharmony from harmony	2
Vowels not read (deletion)	102
TOTAL NUMBER OF ERRORS	226

As can be observed from table 12 above, the speech errors of subjects trained in backness mixed condition were more complex than the errors by harmony subjects and disharmony subjects. They did more errors than harmony and disharmony subjects and they made errors in all categories.

3.1.1.5. Discussion of speech errors made by backness harmony subjects

As has been discussed, speech errors of backness subjects have some common patterns. These results are also parallel with the results of speech errors in Turkish during natural language production (Sofu, 2001). The findings of Sofu (2001) established that Turkish subjects tended to switch the initial phonological units with other initial segments. The speech errors subjects made in these current experiments also indicated that subjects substituted the initial sound of the next word as the initial sound of the word they made a speech error with. Another finding of Sofu (2001) was that vowels tended to switch place with other vowels and consonants with other consonants. This was also confirmed by the speech error data in the artificial language system that was used in our study. As was discussed in detail in the analysis of speech errors in the previous sections, Turkish subjects never substituted vowels for consonants and consonants for vowels. Even if they made a speech error with a consonant, they replaced it with another consonant and never with a vowel.

What is more significant is that subjects who made speech errors in this artificial language system used in the present study still conformed to the phonological properties of the artificial language system. That is, even in their speech errors they followed the CVCV pattern of the language and they still used a sound from the limited set of phonemes that they were given in the artificial language. This finding is also supported in natural language speech errors since Sofu (2001) also showed in her research that even if a word that is not a part of the language's lexicon is created as a result of a speech error, that word still conforms to the phonological rules of the language in question. Sofu (2001) noted that Turkish speakers preserved vowel harmony even in their speech errors, as can be seen from her data: *benim*-----> *banım*, *tırıl tırıl* (combination of *tiril tiril* and *pırıl pırıl*). Our data analysis also showed that harmony subjects maintained harmony in their utterances. Moreover, as indicated by their speech errors, subjects trained on disharmony also maintained disharmony in their speech errors.

A comparison of the list of actual speech errors made by subjects and the list of possible speech errors provided in this chapter point out to the finding that actual speech errors showed some coherent patterns. Usually only one sound (consonant or vowel) was changed within a word. Subjects were most likely to change the voicing feature of consonants. There were a fewer number of cases where subjects modified all three phonetic properties of the original sound, whether it is a vowel or a consonant. It was usually the first vowel which participated in speech errors. This finding is also parallel to previous research (Dell et al, 2000) since they also noted that subjects get the first vowel correct at the expense of the second one.

A detailed comparison of the speech errors of subjects among the three conditions revealed that subjects trained on the mixed condition made more errors with vowels. Whereas the subjects trained in backness harmony and disharmony made 18 and 16 errors, respectively; mixed condition subjects made a total of 39 errors with vowels. This was parallel with the predictions of the experiment in that a lack of pattern is confusing for the subjects and even a disharmonic pattern was easier than no pattern. When the vowel errors of different conditions were compared with each other, it was observed that the properties of the vowel errors shared some common properties. Harmony and disharmony subjects made switch errors more than other errors. However, the mixed condition also showed a different pattern in that those subjects made comparatively much less vowel switch errors. This may be due to the fact that harmony and disharmony subjects did not disrupt the condition they were trained on. There was only one error from each group that resulted in a violation of the condition they were trained on, that is only one harmony subject made a speech error that resulted in disharmony and only one disharmony subject made an error that resulted in harmony. On the other hand, subjects trained on the mixed condition showed their confusion about the lack of a systematic pattern by the errors they made: they created height harmony from two disharmonic words, they created backness harmony from two disharmonic roots and they created disharmony (both in the sense of backness and rounding) from 22 backness harmonic roots. The fact that there were also instances where they also inserted a fifth vowel other than the vowels used in the experiment, [ü], also clearly confirms the predictions that the lack of a pattern is indeed confusing. Neither the harmony nor the disharmony subjects inserted a vowel that is not used in the experiment. It can also be observed from the vowel errors that harmony subjects were more likely to create identical vowels. No speech error resulted in identical vowels in the speech errors of disharmony subjects. It is also worth noting at this point that there were also two instances of vowel identity attested by subjects trained in mixed condition. A closer look at the properties of these errors reveal that the mixed condition subjects created identity from harmonic roots, which also confirms that harmony is closer to vowel identity. This conclusion also comes from the nature of the vowels, since subjects only need to change one feature of a vowel to get identity. It is also interesting to note that in all four cases of vowel identity back/ round vowels were included.

A closer look at the consonant errors among three conditions also revealed similar patterns between the conditions. To start with, subjects in all three groups made more errors with plosive sounds than fricative sounds. The errors subjects made with the 6 plosive sounds used in the experiment, [p] [b] [t] [d] [k] [g], was 93, 36 and 58, respectively for harmony, disharmony and mixed conditions. These numbers reveal that harmony subjects did even more speech errors with plosives compared to mixed group subjects. When these errors with the plosives were analyzed, it was seen that [t] participated in the fewer number of errors in all three groups (total number of errors: 2, 1, 2 respectively for harmony, disharmony and mixed conditions). There were also fewer errors with [k] when compared with other plosives: 3, 1, 4 respectively for harmony, disharmony and mixed conditions. The reason for this may be the fact that subjects made fewer errors with voiceless consonants, that is the total number of errors with voiced consonants were 18, 11, 15 respectively for harmony, disharmony and mixed conditions. When the total number of errors in plosives was taken into consideration, it was clear that this is a much smaller ratio. Subjects from all three conditions made more errors with voiced plosives, [b] [d] [g], compared to their voiceless counterparts. As mentioned before, most of the errors with the voiced consonants was replacing them with their voiceless counterpart.

As will be remembered, there were four fricatives used in the experiment: [f] [s] and [v] [z]. Among the fricatives, the voiceless labio-dental fricative [v] was the sound which was mostly replaced with other sounds in all three groups: 23, 15, 20 respectively for harmony, disharmony and mixed conditions. It was again the voiced fricatives, [v] and [z], rather than the voiceless fricatives that participated in more speech errors. The ratio of voiced to voiceless fricatives was 37/15, 25/ 9, 22/12, respectively for harmony, disharmony and mixed conditions. These ratios also clearly reflected that subjects had more problems with the voiced fricatives. Most of the time the voiced fricatives were replaced by their voiceless counterparts as a result of speech errors.

These results indicated that subjects follow the phonological rules of the system they were exposed to whether it is harmony or disharmony. All they needed was a consistent pattern. As can be observed from the speech errors of mixed condition subjects, it is possible to state that they cannot generalize a rule if they are exposed to both a harmonic and disharmonic system. This further indicates that they could only learn a system if it had a coherent pattern. As long as the system had a pattern that was consistent, then the subjects could learn a pattern that was not even found in their native language, as can be observed from the data of the disharmony subjects and the data of height harmony subjects.

3.1.2. Height Harmony Errors

As stated in the method section, the same experiment made with backness harmony was also repeated with height harmony. Height harmony is a type of harmony that can be found in natural languages as in the Romance dialects Lena and Calvello (Campos-Astorkiza, 2007). The goal of the experiment in height harmony was to test whether Turkish subjects would be able to learn another artificial system based on vowel harmony, but this time a vowel harmony that was completely different from their native language. This would in turn have implications for the universal nature of vowel harmony.

The speech errors subjects made were transcribed by the experimenter. Following the same method used for backness harmony subjects, in order to test for errors, two native speakers of Turkish also transcribed 80% of the recordings. To avoid any bias that can be caused by the phonology of Turkish, 40% of the tapes were also transcribed by a Polish speaker.

The tapes were not acoustically analyzed. The tapes with the recordings of the subjects were listened by the experimenter and anything that sounded different than the actual item was noted. The errors for each subject were noted this way and then the type of errors were categorized.

In the same pattern with the backness harmony subjects, the errors of height harmony subjects are provided in two ways: 1. The number of errors (consonant, vowel, switch errors) 2. The rate of errors (which shows the average number of errors for each subject). The speech errors were analyzed according to the categories provided by Fromkin (1971). Fromkin categorized speech errors as: 1. shift and exchange, 2. perseveration, 3. anticipation, 4. deletion, 5. addition, 6. substitution, 7. blend.

3.1.2.1. Speech Errors of Harmony Subjects trained in Height Harmony Condition

Subjects trained in the harmony condition of the height harmony were trained on words that were harmonic in respect of their height feature. That is, if the first vowel of the word is high, then another high vowel would follow, as predicted by height harmony rules. It should again be noted that the rules of height harmony designed for this artificial language were very strict as was the case for backness harmony. Since there were again vowels used from the set [e], [i], [o], [u]; high vowels ([i] and [u]) did not agree in terms of their backness frontness or rounding features. With the same logic, low vowels ([e] and [o]) also did not have common rounding or backness/frontness features. In short, the only feature common for the vowels was their height feature. To illustrate, some words used in the actual experiment are: *bivu, kezo, vobe, fuzi*. As can be observed, all the vowels in the words agree in their height features.

Harmony subjects trained in the height condition saw two vowels that agreed in their height feature, and also their rounding feature as a result of the nature of the four vowels used in the experiment. As discussed in the first chapter, the errors for harmony subjects trained in the height harmony condition were categorized as:

1. Consonant errors (which show the error rate)
   Switching the order of consonants, repeating the first consonant etc.
   ex: sezo → seso
   kuvi → kuki

The number of consonants not pronounced will also be provided under deletion.

3. Errors in the vowels:
    a. Keeping the first vowel and replacing the second vowel with it (perseveration)

       ex: sezo → seze
    b. Keeping the second vowel and replacing the first vowel with it (anticipation)

       ex: sezo → sozo

As can be seen from the table 13 below, these two categories (a) and (b) were collapsed into one for the sake of analysis.

   c. Switching the order of the two vowels within the word (exchange)

      ex: sezo → soze
   d. Creating disharmony (substitution)

      ex: sezo → sezi

As can be seen from the example above, this type of speech error included one of the four vowels used in the experiment but the properties of the vowel clashes with the properties of the vowel in the item and the result was disharmonic.

   e. Substituting another vowel that is not one of the four vowels (o, u, e, i) used (other vowel errors)

      ex: sezo → sazo

3.1.2.1.1. Possible Speech Errors

The following table displays the properties of the speech errors in detail. Here is a list of all the possible errors they could have made:

1. ***Repeating first vowel (perseveration, identity):*** This included taking the first vowel and replacing the second vowel in the item with the first vowel, thus creating two identical vowels in the word. Although this type of error was not a violation of height

harmony, it was an example of creating an extreme vowel harmony where vowels agreed in all features since they were identical.

o-e → o-o (fobe → fobo)

u-i → u-u (fubi → fubu)

e-o→ e-e (febo → febe)

o-e → i-i (fobe → fibi)

2. ***Repeating the second vowel (anticipation, identity):*** This included taking the second vowel and replacing it with the first vowel in the item, thus creating two identical vowels in the word. It should be noted that, this was not a violation of vowel harmony. On the contrary, it was an example of creating an extreme vowel harmony where vowels agree in height features since they were completely identical.

o-e → e-e (fobe → febe)

o-e → o-o (fobe → fobo)

e-o → e-e (febo → febe)

e-o → o-o (febo → fobo)

u-i → i-i (fubi → fibi)

u-i → u-u (fubi → fubu)

i-u → i-i (fibu → fibi)

i-u → u-u (fibu → fubu)

3. ***Switching vowels (exchange):*** This was achieved by switching the order of the two vowels in the item, so that what used to be the second vowel got to be the first vowel in the new item created and the first vowel in the original item became the second vowel. Again, it should be noted that there is no violation of height vowel harmony in this speech error; since the vowels were the same and the combination of the vowels were the same, it was only the order that was changed.

i-u → u-i (fibu → fubi)

u- i → o-u (fubi → fibu)

e-o → i-e (febo → fobe)

o-e → e-o (fobe → febo)

4. ***Another vowel (substitution):*** This case was the example where vowel harmony may be violated. This was the case when subjects replaced one of the vowels in the word with another vowel used in the experiment. However, the vowel the subject used was one of the four vowels used in the experiment. But since the vowel used did not agree with the height features of the other vowel in the item the result was disharmonic.

o-e → o- u (fobe → fobu)

o-e→ o-i (fobe → fobi)

o-e→ i-o (fobe → fibo)

o-e → u-e (fobe → fube)

o-e → e-u (fobe → febu)

o-e → u-o (fobe → fubo)

o-e → i-e (fobe → fibe)

o-e → e-i (fobe → febi)

e-o → e-i (febo → febi)

e-o → i-e (febo → fibe)

e-o → u-o (febo → fubo)

e-o → o- u (febo → fobu)

e-o → e-u (febo → febu)

e-o → u-e (febo → fube)

e-o → i-o (febo → fibo)

e-o → o-i (febo → fobi)

u-i → u- e (fubi → fube)

u- i → e- u (fubi →febu)

u-i → u-o (fubi → fubo)

u-i → o-u (fubi →fobu)

u-i → o-i (fubi → fobi)

u-i → i-o (fubi → fibo)

u-i → i-e (fubi → fibe)

u-i → e-i (fubi → febi)

i-u → e-i (fibu → febi)

i-u → i-e (fibu → fibe)

i-u → i-o (fibu → fibo)

i-u → o-i (fibu → fobi)

i-u → o-u (fibu →fobu)

i-u → u-o (fibu →fubo)

i-u → e- u (fibu →febu)

i-u → u- e (fibu →fube)

This list illustrates all the possible errors in this set.

5. ***Another vowel not used in the experiment:*** This was another example of vowel harmony being violated. Only the vowels [e], [i] and [o], [u] were used in the experiment. Insertion of a vowel that was not one of these four vowels would result in disharmony in terms of the system. Insertion of [ı], [ö], [ü] or [a] would all result in disharmony when the rules of the artificial language are considered. Only the possible list of errors with o-e in the target item are given below:

o-e → o- a (fobe → foba)

o-e → a- o (fobe → fabo)

o-e → o-ü (fobe → fobü)

o-e → ü-o (fobe → fübo)

o-e → o- ı (fobe → fobı)

o-e → ı- o (fobe → fıbo)

o-e → o-ö (fobe → fobö)

o-e → ö-o (fobe → föbo)

o-e → a-u (fobe → fabu)

o-e → u-a (fobe → fuba)

o-e → ı-u (fobe → fıbu)

o-e → u-ı (fobe → fubı)

o-e → ü-u (fobe → fübu)

o-e → u-ü (fobe → fubü)

o-e → ö-u (fobe → föbu)

o-e → u-ö (fobe → fubö)

6. Consonant errors: Consonant errors included switching the place of the consonants, changing the voicing of the consonant, changing the place of articulation feature of the consonant, changing the manner of articulation feature of the consonant, not pronouncing some consonants, creating identical consonants by copying the first or the second consonant. When consonant errors were counted only changes in consonants were noted, changes in the vowels fall into one of the previous categories. Here are just a few possible examples of consonant errors, the list does not exhaust all the possible errors:

g → b (gobe → bobe)

d → t (pidu → pitu)

v → g (voge → goge)

g → v (givu → vivu)

b → ∅ (pubi → pu)

f → v (fubi → vubi)

s → z (soze → zoze)

v → f (vibu → fibu)

t → g (tudi → gudi)

t → b (tivu → tibu)

s → z (sode → zode)

3.1.2.1.2. Actual Participant Errors

After giving the list of all possible errors, the actual errors the subjects produced will be provided. As can be observed from the following table, subjects did not exhaust all the possible errors they could have done. Rather, their errors tended to fall into certain categories.

3.1.2.1.2.1. Vowel errors

The table 13 below provides the errors on the first column along with the category of the errors. So, [i]-[u] stands for a word with [i]-[u] sequence such as *fibu*. Thus, i-u → i-i, illustrates *fibu* being pronounced as *fibi* as a result of speech error. The second column represents the rate of speech errors, that is the number of errors divided by the number of subjects.

Table 13: The list of speech errors in vowels of subjects trained in harmony condition of height harmony

Vowel errors	**Total**	**Rate**
Repeat 1st V (perseveration)		
i-u→ i-i	1	0.083
Repeat 2nd V (anticipation)		
o- e→ e- e	1	0.083
Switch Vs (exchange)		
e- o→ o- e	6	0.65
o- e → e-o	4	0.33
u- i → i-u	3	0.25
i- u → u-i	2	0.25
Other vowel errors	0	0
Another vowel	0	0
Disharmony		
e-o → e-u	1	0.083
i- u → i-o	3	0.25
u-i → o-i	1	0.083

As can be observed from table 13 above, some errors were more common than others. If we compare these actual errors to the list of all possible errors, we see that the speech errors of subjects tend to fall into certain categories. To illustrate, there were no examples of speech errors where a vowel not used in the experiment was substituted. This illustrates that subjects are aware of the phonological properties of the artificial language that they were trained on and they maintained those properties even in their speech errors.

There were a total of 22 vowel errors made by height harmony subjects. The fact that there were only a total of five speech errors that resulted in height disharmony indicates that subjects learnt the condition they were trained on since they even kept height harmony in most of their mistakes. The other finding that there was no vowel instead of the four vowels used in the experiment inserted by subjects in the speech errors also suggested that the participants learned the specific phonological properties of the artificial system they were trained on. Otherwise, since all participants speak Turkish as their mother language they could have inserted any of the eight vowels four of which were not used in this artificial language.

A detailed analysis of the vowel errors indicate that the non-high vowels used in this experiment, [o] and [e], participated in slightly more speech errors compared with the high vowels [i] and [u]. Whereas, [o] and [e] participated in a total of 12 speech errors, [i] and [u] participated in a total of 10 errors. Especially there seemed to be a difference in the speech errors where the order of vowels in the original words was switched, non high vowels [o] and [e] had twice as much exchange errors than the high vowels [u] and [i]. The total number of switching errors including [o] and [e] was 10, and the total number of switching errors with [u] and [i] was 5.

There was only one instance where the first vowel and the second vowel was repeated, thus resulting in identity. Although this was noted as a speech error, it should be remembered that actually identity was not a violation of vowel harmony, on the contrary it was an example to an extreme case of harmony. When the first vowel was repeated, it was with the string [i] and [u], thus resulting in [i] and [i]. The example with the second vowel being repeated was with [o] and [e], where the resulting string was [e] and [e].

The most striking part of the analysis was the actual errors where one of the vowels in the original string was substituted with another vowel by the subjects. As can be observed from the table above, of these errors the most common was [i]- [u] string being modified as [i]-[o] string. This error occurred a total of three times across subjects. This error however, violated the conditions of height harmony in this experiment. Even more interesting was that the resulting string, [i]-[o], also violated backness harmony. That is why this error cannot be explained as an error where the experimental item waSs modified in a way to approach to the rules of the subjects' native language. Also, the other form of this error, where [u]-[i] was pronounced as [o]-[i] was also attested again resulting in height disharmony. The final type of error resulting in height disharmony was the use of [e]-[u] string instead of the original [e]-[o] string. This was also a violation of the height harmony rules employed in the experiment. The resulting string [e]-[u] agreed neither in height nor in backness or rounding. The result was complete disharmony.

3.1.2.1.2.2. Consonant errors by height harmony subjects

After analyzing the vowel errors made by height harmony subjects, the consonant errors produced by the subjects were analyzed. As will be remembered from the list of possible errors, subjects could either switch the order of original consonants or replace the first or the second consonant with another consonant.

Table 14: Speech errors with consonants by height harmony subjects

Consonant errors	**Total number**	**Rate**
b → d	4	0.33
b → g	1	0.083
b → p	10	0.83

b → v	1	0.083
d → b	1	0.083
d → g	1	0.083
d → t	1	0.083
f → p	1	0.083
f → k	1	0.083
f → p	1	0.083
f → t	1	0.083
f → v	1	0.083
g → d	1	0.083
g → k	1	0.083
g → v	2	0.16
g → z	2	0.16
k → g	2	0.16
p → b	2	0.16
p → v	1	0.083
s → f	1	0.083
s → t	1	0.083
s → z	1	0.083
v → b	4	0.33
v → d	1	0.083
v → f	4	0.33
v → g	1	0.083
v → z	9	0.75
z→ b	1	0.083
z → d	1	0.083
z → s	1	0.083
z → t	1	0.083

When the speech errors of subjects trained in the height harmony are analyzed, certain patterns of errors are observed. Subjects made a total of 61 consonant errors. First of all, the most common error for most of the consonants was to change the voicing feature of the consonant, while keeping the place and manner of articulation constant. This was the most common error attested with consonants [b], [d], [f], [k], [g], [p], [s] and [z]. Actually for [k], this was the only error attested. The only exception was [v].

a) Errors with plosives

The substitutions for the voiced bilabial plosive sound [b] were [d], [g], [p] and [v]. As mentioned above, the most common error was to replace [b] with [p], which occurred a total of ten times across subjects. This was interesting since only one feature, voicing, needed to be changed for this speech error between [b] and [p]. The next most common substitution for [b] was [d]. Changing [b] into [d] requires only the change of point of articulation. Manner of articulation and voicing features do not need to be changed, since both [b] and [d] are voiced and they are both oral plosives. The only difference is that [b] is bilabial and [d] is denti-alveolar. Switching [b] with [g] also employs the modification of the same feature, that is place of articulation. Since [g] is a voiced velar oral stop and [b] is a voiced bilabial oral stop, only the point of articulation needs to be changed from [b] to [g]. Changing [b] to [v], requires more than changing one feature. Because [b] and [v] differ not only in place of articulation but also in the manner of articulation feature. The only feature they actually share is the state of glottis. Since [v] is a voiced labio-dental fricative, the subject had to change both the manner and the point of articulation feature.

When the denti-alveolar voiced plosive [d] was replaced with another sound it was one of the sounds [b], [g] and [t]; the number of errors was equally common. Substitution of [d] with [b], requires the change of one feature only. Since both [d] and [b] are voiced plosives, the only feature they differ is the point of articulation. [d] is denti-alveolar whereas [b] is bilabial. That is, changing [d] to [b] requires fronting of the place of articulation features. The other consonant that [d] was replaced with was [g]. This replacement also needed a change in a single feature, the place of articulation feature.

Since [g] is also a voiced sound and a plosive, only the point of articulation needed to be altered, [g] being velar. The articulators need to move five steps back to get to the velar sound [g]. The change between [d] and [t] is the simplest one as mentioned before since only voicing feature is altered. [d] and [t] are both denti-alveolar sounds and they are both plosives; the only feature they differ is voicing.

The voiced velar plosive [g] was replaced by four different consonants being: [d], [k], [v] and [z]. As before, there were common features among these consonants. First of all, [g] and [k] share all features about manner of articulation and point of articulation, the only feature they differ on is the voicing feature. When it comes to voicing, [g], [d], [v] and [z] all share the feature of being voiced. [d] is also similar to [g] in terms of manner of articulation feature, since both are plosives. [v] and [z] differ from [g] since they are fricatives.

It is interesting to note that the only consonant that [k] was replaced with was [g]. The two sounds are similar in two aspects: manner and place of articulation. They only differ in terms of voicing since [k] is voiceless but [g] is voiced.

The speech errors with [p] included substitution by [b] and [v]. An analysis of these errors reveals the similarities of the sounds. All three sounds are anterior consonants, either bilabial or labio-dental. [p] and [b] share all their features of manner of articulation and place of articulation, but only differ in voicing.

b) Errors with fricatives

Speech errors with [f] included substitution with [b], [d], [p], [t] and [v], each with one instance. These consonants, again, share certain features. They share the feature of being all anterior consonants. [f] and [v] share all features except voicing. Although [f] is voiceless [p], [t] and [v] are voiced. [f] and [p], [t] and [k] differ in both manner and place of articulation features.

The voiceless denti-alveolar fricative [s] was replaced by three different sounds: [f], [t] and [z]. All of these sounds are dental sounds. [s] and [z] share all features except voicing feature, since [z] is the voiced counterpart of [s]. When it comes to [s] and [f], they share the manner of articulation feature in addition to the voicing feature. [s] and [t] also share two features, that of being denti-alveolar and being voiceless; they only differ in manner of articulation aspect since [t] is an oral stop.

The consonant which was replaced by the highest number of different consonants was [v], since it was replaced by five different consonants being: [b], [d], [f], [g] and [z]. There were common features among these consonants. First of all, [v] and [f] share all features about manner of articulation and point of articulation, the only feature they differ on is the voicing feature. When it comes to voicing, [b], [d], [g] ,[z] and [v] all share the feature of being voiced. [z] and [f] also share the manner of articulation feature with the original vowel [v] since they are all fricatives. As can be seen from the table above, the most common error seem to be replacing [v] with [z], however a detailed analysis reveals that all the nine errors of replacing these two consonant was conducted by the same subject (79HH). So, it would not be right to generalize upon one subject's error.

The speech errors with the voiced denti-alveolar fricative sound [z] include replacement with [b], [d], [s] and [t]. There are also certain features shared among those consonants. [z] and [s] are both denti-alveolar oral stops, and they only differ in voicing. [z] and [b], [d] share the feature of being voiced. [z] and [t] share the feature of being denti-alveolar but they differ in the voicing and manner of articulation features.

Table 15: Overview of the speech errors of height harmony subjects

Consonant Errors	61
Consonants not read (deletion)	74
Total consonant errors	135
Vowel identity (perseveration + anticipation)	2
Vowel switch errors (exchange)	15
Another Vowel (substitution)	0
Other Vowel Errors	0
Total vowel errors	96
Creating disharmony from harmony	5
Vowels not read (deletion)	74
TOTAL NUMBER OF ERRORS	231

The speech errors of subjects trained in the harmony condition of height harmony indicate that a pattern can be found even in the speech errors. Consonants were more prone to speech errors. When the possible speech errors listed earlier in this section are compared with the actual speech errors this is clearly seen. Subjects tended to change a minimal number of features in their errors. This holds true for both consonant and vowel errors. They were more inclined to modify one sound in a single word than modifying more than one. In other words, subjects were likely to remain as faithful as they can be to the original sounds even in their speech errors.

3.1.2.2. Speech Errors of Disharmony Subjects trained in Height Harmony Condition

In height disharmony items, there were again vowels used from the set [e], [i], [o], [u]. As has been described in the method section, subjects trained in the disharmony condition of the height harmony saw words that had the combination of [e]- [u] or [i]- [o] in either order. That is, the words they saw were disharmonic in respect of their height feature. If the first vowel of the word was high then the next vowel would be non-high, since the system was defined as height disharmony. It should again be noted that the rules of height disharmony designed for this artificial language were very strict as was the case for backness harmony. To illustrate, some words used in the actual experiment are: *bivo, kezu, vobi, fozi*. As can be observed, all the vowels in the words disagree in their height features. By definition, the words that violated height harmony also violated backness harmony so they were disharmonic in both senses of harmony used in this artificial language.

As discussed in the first chapter, the errors for harmony subjects trained in the height disharmony condition were categorized as (all examples taken from height disharmony):

1. Consonant errors (which show the error rate)

   Switching the order of consonants, repeating the first consonant etc. It should be noted that this type of error only includes the consonants.

   ex: sezu → sesu

   kivo → kiko

   The number of consonants not pronounced will also be provided under deletion.

4. Errors in the vowels:
   a. Keeping the first vowel and replacing the second vowel with it (perseveration)

      ex: sezu → seze
   b. Keeping the second vowel and replacing the first vowel with it (anticipation)

      ex: sezu → suzu

As can be seen from the table below, these two categories (a) and (b) are collapsed into one for the sake of analysis.

   c. Switching the order of the two vowels within the word (exchange)

      ex: sezu → suze
   d. Creating disharmony (substitution)

      ex: sezu → sezi

As can be seen from the example above, this type of speech error includes one of the four vowels used in the experiment but the properties of the vowel clashes with the properties of the vowel in the item and the result is disharmonic.

e. Substituting another vowel that is not one of the four vowels (o, u, e, i) used (other vowel errors)
ex: sezu → sazu

3.1.2.2.1. Possible Speech Errors

The following table 16 displays the properties of the speech errors of height disharmony subjects in detail. Here is a list of all the possible errors they could have made:

1. ***Repeating first vowel (perseveration, identity):*** This included taking the first vowel and replacing the second vowel in the item with the first vowel, thus creating two identical vowels in the word. Although this type of error was not a violation of height harmony, it was an example of creating an extreme vowel harmony where vowels agree in all features in that they were identical.

o-i → o-o (fobi → fobo)

i-o → i-i (fibo → fibi)

e-u→ e-e (febu → febe)

u-e → u-u (fube → fubu)

2. ***Repeating the second vowel (anticipation, identity):*** This included taking the second vowel and replacing the first vowel in the item, thus creating two identical vowels in the word. It should be noted that, this was also not a violation of vowel harmony. On the contrary, it was an example of creating an extreme vowel harmony where vowels agreed in height features in that they were completely identical.

o-i → i-i (fobi → fibi)

i-o → o-o (fibo → fobo)

e-u → u-u (febu → fubu)

u-e → e-e (fube → febe)

3. ***Switching vowels (exchange):*** This is achieved by switching the order of the two vowels in the item, so that what used to be the second vowel got to be the first vowel in the new item created and the first vowel in the original item became the second vowel.

Again, it should be noted that there was no violation of height vowel harmony in this speech error; since the vowels were the same and the combination of the vowels were the same, it was only the order that was changed.

i-o → o-i (fibo → fobi)

o- i → i-o (fobi → fibo)

e-u → u-e (febu → fube)

u-e → e-u (fube → febu)

4. ***Another vowel (substitution):*** This case was the example where vowel harmony may be violated. This was the case when subjects replaced one of the vowels in the word with another vowel used in the experiment. However, the vowel the subject used was one of the four vowels used in the experiment. But since the vowel used did not agree with the height features of the other vowel in the item the result was not disharmonic as the items the subjects were trained on.

u-e → o- u (fube → fobu)

u-e→ o- i (fube → fobi)

u-e→ i- o (fube → fibo)

u-e → u- o (fube → fubo)

u-e → i-e (fube → fibe)

u-e → e-i (fube → febi)

u-e → u-i (fube → fubi)

u-e → i-u (fube → fibu)

u-e → e-o (fube → febo)

u-e → o-e (fube → fobe)

e-u → e-i (febu → febi)

e-u → i-e (febu → fibe)

e-u → u-o (febu → fubo)

e-u → o- u (febu → fobu)

e-u → i-u (febu → fibu)

e-u → u-i (febu → fubi)

e-u → e-o (febu → febo)

e-u → o-e (febu → fobe)

u-e → u- i (fube → fubi)

u- e → i- u (fube →fibu)

u-e → u-o (fube → fubo)

u-e → o-u (fube →fobu)

u-e → o-i (fube → fobi)

u-e → i-o (fube → fibo)

u-e → i-e (fube → fibe)

u-e → e-i (fube → febi)

i-o→ e-i (fibo → febi)

i-o → i-e (fibo → fibe)

i-o → i-u (fibo → fibu)

i-o → u-i (fibo → fubi)

i-o → o-u (fibo →fobu)

i-o → u-o (fibo →fubo)

i-o → e- u (fibo →febu)

i-o → u- o (fibu →fube)

This list illustrates all the possible errors in this set.

5. ***Another vowel not used in the experiment:*** This is another example of vowel disharmony being violated. Only the vowels [e], [i] and [o], [u] were used in the experiment. Insertion of a vowel that was not one of these four vowels would result in disharmony in terms of the system. Insertion of [ı], [ö], [ü] or [a] would all result in disharmony when the rules of the artificial language were considered. Only the possible list of errors with o-i in the target disharmonic item is given below:

o-i → o- a (fobi → foba)

o-i → a- o (fobi → fabo)

o-i → o-ü (fobi → fobü)

o-i → ü-o (fobi → fübo)

o-i → o- ı (fobi → fobı)

o-i → ı- o (fobi → fıbo)

o-i → o-ö (fobi → fobö)

o-i → ö-o (fobi → föbo)

o-i → a-u (fobi → fabu)

o-i → u-a (fobi → fuba)

o-i → ı-u (fobi → fıbu)

o-i → u-ı (fobi → fubı)

o-i → ü-u (fobi → fübu)

o-i → u-ü (fobi → fubü)

o-i → ö-u (fobi → föbu)

o-i → u-ö (fobi → fubö)

6. Consonant errors: Consonant errors include switching the place of the consonants, changing the voicing of the consonant, changing the place of articulation feature of the consonant, changing the manner of articulation feature of the consonant, not pronouncing some consonants, creating identical consonants by copying the first or the second consonant. When consonant errors were counted only changes in consonants were noted, changes in the vowels fell into one of the previous categories. Here are just a few possible examples of consonant errors, the list does not exhaust all the possible errors:

g → b (gobi → bobi)

d → t (pido → pito)

v → g (vogi → gogi)

g → v (givo → vivo)

b → ∅ (pobi → po)

f → v (fube → vube)

s → z (suze → zuze)

v → f (vibo → fibo)

t → g (tude → gude)

t → b (tivo → tibo)

s → z (sodi → zodi)

3.1.2.2.2. Actual Participant Errors

After giving the list of all possible errors in the previous section, the actual errors the subjects produced wil be provided in this section. As can be observed from the following table 16, subjects did not exhaust all the possible errors they could have done. Rather, their errors tended to fall into certain categories.

3.1.2.2.2.1. Vowel errors

The following table 16 provides the errors on the first column along with the category of the errors. So, [o]-[i] stands for a word with [o]-[i] sequence such as *fobi*. Thus, o-i → o-o, illustrates *fobi* being pronounced as *fobo* as a result of speech error. The second column represents the rate of speech errors, that is the number of errors divided by the number of subjects.

Table 16: The list of speech errors in vowels of subjects trained in disharmony condition of height harmony

	Total	**Average**
Repeat 1st V (perseveration)	0	0
Repeat 2nd V (anticipation)	0	0
Switch Vs (exchange)		
u-e → e-u	2	0.16
i-o → o-i	2	0.16
e- u → u- e	2	0.16
Other vowel errors	0	0
Another vowel	0	0
Creating harmony		
o-i → o-e	1	0.083
i-o → i-e	1	0.083

As can be observed from table 16 above, some errors were more common than others. If we compare these actual errors to the list of all possible errors, we see that the speech errors of subjects tend to fall into certain categories. To illustrate, there were no examples of speech errors where a vowel not used in the experiment was substituted. This illustrates that subjects were aware of the phonological properties of the artificial language system that they were trained on, even if the language was defined on height vowel disharmony and they maintained those properties even in their speech errors.

Subjects trained in the height disharmony condition made a total of 8 vowel errors. The fact that there was only one speech error that resulted in height harmony (o-i → o-e) indicated that subjects learnt the condition they were trained on since they even kept height disharmony in most of their mistakes. There was also one instance where the subject created an item that obeys backness harmony, which was not the condition they were trained on. When the subject replaced [i] with [e] and used o-e string in the word rather than the original o-i string, the result was an item that is an example of backness vowel harmony.

There were a total of six switch errors, where the disharmony was kept but only the order of the vowels were changed. This was an interesting error since it reveals that the subjects were aware of the properties of the errors and they tended to keep it even in their speech errors. The e-u pair (in either order) participated in more switch errors than i-o pair. The other finding that there was no vowel instead of the four vowels used in the experiment inserted by subjects in the speech errors also suggested that the participants learned the specific phonological properties of the artificial system they were trained on. Otherwise, since all participants spoke Turkish as their mother language they could have inserted any of the eight vowels four of which were not used in this artificial language.

A detailed analysis of the vowel errors indicate that [o] and [i], participated in an equal number of errors with the high vowels [e] and [u] in total. However, in switching errors there were more items that were switched that included [e] and [u] in either order.

There was no instance where the first vowel or the second vowel was repeated, resulting in identity. It should be remembered that this was an example of complete identity. Since the subjects did not make any errors of this kind we can conclude that they are already aware that the vowels in the words are very different from each other and they did not make them identical even in their speech errors.

3.1.2.2.2.2. Consonant errors

After analyzing the vowel errors made by height disharmony subjects, the actual consonant errors subjects made will be analyzed in this section. As will be remembered from the list of possible errors, subjects could either switch the order of original consonants or replace the first or the second consonant with another consonant. The following table 17 provides a list of all consonant errors subjects trained in the height disharmony condition made.

Table 17: Speech errors with consonants by height disharmony subjects

Consonant errors	**Total error**	**Rate**
b → d	7	0.58
b → g	2	0.16
b → p	4	0.33
b → v	2	0.16
b → s	1	0.083
b → z	1	0.083
d → b	3	0.25
d → g	3	0.25
d → p	1	0.083
d → z	2	0.16
f → p	2	0.16
f → t	1	0.083

f → v	2	0.16
g → b	8	0.66
g → d	3	0.25
g → p	1	0.083
g → k	1	0.083
k → b	1	0.083
k → g	1	0.083
k → p	1	0.083
p → b	4	0.33
p → f	6	0.5
p → g	2	0.16
p → k	2	0.16
p → v	1	0.083
s → f	1	0.083
s → z	4	0.33
t → k	1	0.083
t → p	1	0.083
v → b	3	0.25
v → d	1	0.083
v → f	14	1.16
v → g	1	0.083
v→ z	6	0.5
z → d	1	0.083
z → g	1	0.083
z → s	3	0.25
z → v	1	0.083

When the speech errors of subjects trained in the height disharmony were analyzed, it was observed that the errors were in certain patterns. There were a total of 38 different types of errors, but some errors were more common than others. First of all, the most common error for most of the consonants was to change the voicing feature of the consonant, while keeping the place and manner of articulation constant. This was the most common error attested with consonants [f], [k], [s], [v], [z]. For the consonants [b], [p] and [g], although there were consonant errors where the original consonant was replaced with its counterpart in voicing, this was not the most common error. The only exceptions were [d] and [t] where errors including their voiced counterparts were not attested.

a) Errors with plosives

The substitutions for the voiced bilabial plosive sound [b] were [d], [g], [p], [v], [s] and [z]. When we analyzed these errors, we saw that there were common properties between the original consonant and the consonant that it was replaced with. The most common error was to replace [b] with [d], which occurred a total of seven times across subjects. This was interesting because only one single feature, place of articulation needs to be changed to modify [b] with [d]. Voicing and manner or articulation did not need to be changed for this speech error between [b] and [d] since they are both plosives and they are both voiced. The next most common substitution for [b] was [p]. Changing [b] into [p] also required only a single change in the features, the change of voicing. Manner of articulation and place of articulation features did not need to be changed, since both [b] and [p] are bilabial oral plosives. Another speech error with [b] that required only a single change in the features of the original sound was its substitution by [g]. Since [g] is also a voiced oral plosive, they only differ in the place of articulation. [g] is produced further back in the mouth than [b], since [g] is a velar sound and [b] is bilabial. The other speech errors with [b] all require a change in at least two features: its being replaced by [v], [s] and [z]. Replacing [b] with [v] requires a change in both the manner and the place of articulation features, since [b] is a bilabial plosive and [v] is a labio-dental fricative. They only share the feature of voicing, both being voiced consonants. The substitution of [b] with [s] requires the modification of all three properties, since they do not share any common property among each other. Since [s] is a voiceless denti-alveolar fricative, it does not have any common feature with the voiced bilabial plosive [b]. Going from [b] to [z] means keeping the property of being voiceless and changing the other two features, that of place and manner of articulation. [z] is a voiced denti-alveolar fricative whereas the original sound [b] is neither a fricative nor denti-alveolar.

The speech errors subjects made with [d] included substitution by [b], [g], [p] and [z]. The most common of these errors was the substitution of [b] and [g], each occurring a total of three times. It is interesting to note that there was no speech error attested where [d] was replaced by its voiceless counterpart [t]. Thus, all errors with [d] include a modification features other than voicing. Replacing [d] with [b] requires the modification of place of articulation feature, since [d] is a denti-alveolar and [b] is a bilabial sound. There is no need to change the manner of articulation feature to replace [d] with [b] since both sounds are oral stops. Replacing [d] with [g] also requires the change of place of articulation feature, since [d] is denti- alveolar and [g] is velar. Substituting [d] with [p], on the other hand, requires changing two features of the original sound. The subjects had to modify both the voicing and the place of articulation features, since [d] is a denti-alveolar and [p] is a bilabial and they also differ in voicing. The only feature that does not require modification is the manner of articulation feature since they share the feature of being plosives. Replacing [d] with [z] requires changing a single feature. Due to the fact that [d] and [z] are both voiced and denti-alveolar the subject did not need to modify the voicing and place of articulation feature. The only feature a subject needed to modifyto make [d] into [z] was to change the manner of articulation of the original sound, since [d] is a plosive but [z] is a fricative.

The speech errors with the voiced velar plosive [g] included its substitution by either [b], [d], [p] or its voiceless counterpart [k]. There were again some similarities between [g] and the sounds it was replaced with. Substituting [b] with [g] was the most common of the speech errors, as can be observed from the speech errors table above. This speech error required a change in a single feature, since these two consonants already share the features of manner of articulation and the state of glottis. They only differ in the aspect of point of articulation in that [b] is bilabial whereas [g] is produced further back in the mouth, it being a velar sound. So, a subject who replaced [g] with [b] solely needed to modify the point of articulation feature. The second most common speech error with the consonant [g] was its replacement by [d], which occurred a total of three times. This error required a modification of only one feature of the original consonant, that of point of articulation. Due to the fact that [g] and [d] already share the features of manner of articulation and the state of glottis, the subject needed to modify only the feature of place of articulations since [g] is velar but [d] is denti-alveolar. Another error with the voiced velar plosive [g] was its substitution with the voiceless bilabial plosive [p]. This modification required a change of two features, that of voicing and the place of articulation. The last error with the consonant [g] was its being replaced with its voiced counterpart [k], which occurred a total of one time.

The speech errors with the voiceless velar plosive [k] were of three types, it was either replaced by [b], [g] or [p]. When the subject used the voiced bilabial plosive [b] instead of [k], this meant that the subject modified two features of the original consonant. [k] and [b] have the same manner of articulation since both sounds are plosives, however they differ in point of articulation and the state of glottis features. [k] is a voiceless velar plosive however, [b] is a voiced bilabial plosive. The second type of error with the consonant [k] was its being replaced by [g], which is its voiced counterpart. So, the only feature the subject had to change was the voicing since [k] and [g] already have the same values for manner and point of articulation, both being plosive and velar. The third type of speech error with [k] was its being replaced by the voiceless bilabial plosive [p]. This speech error required a change in one feature only, since [k] and [p] already share the features of being voiceless and being oral stops. They only differ in point of articulation since [k] is velar and [p] is bilabial.

The consonant which was replaced by the highest number of different consonants was [p], since it was replaced by five different consonants being: [p], [f], [g], [k] and [v]. There were common features among these consonants. First of all, [p] and [b] share all features about manner of articulation and point of articulation, the only feature they differ on is the voicing feature. When it comes to voicing, [p], [f] and [k] all share the feature of being voiced. [b], [k] and [g] also share the manner of articulation feature with the original vowel [p] since they are all oral stops. As can be seen from the table above, the most common error seems to be replacing [p] with [f], which occurred a total of six times. This error required a change of two features of the original consonant, change of manner and point of articulation. [p] is a bilabial plosive whereas [f] is a labio-dental fricative. Replacing [p] with [g], on the other hand, requires changing the point of articulation and the state of glottis features of the original consonant since [p] and [g] already share the manner of articulation features both being plosives. The third type of speech error with [p] was replacing it with [k]. This speech error meant the modification of only the point of articulation feature, since [p] and [k] already share manner of articulation and voicing features both being voiceless plosives. They differ in point of articulation feature since [p] is produced with two lips as a bilabial sound, but [k] is produced further back in the mouth since it is a velar sound. The last type of speech error with the consonant [p] was replacing it with [v], which was the least common error since it only occurred once. This error meant a modification of all three features since [p] and [v] do not have any common feature. The subject had to modify the place and manner of articulation and the state of the glottis change the voiceless bilabial plosive [p] with [v], since [v] is a voiced labio-dental fricative.

The errors with the voiceless denti-alveolar plosive [t] include substitution by [p] and [k]. These consonants, again, share certain features. [t] and [p] share the feature of being anterior consonants, since [t] is denti-alveolar and [p] is bilabial. [t] and [p] actually differ only in the exact place of articulation, since they are both voiceless and plosives. Replacing [t] with [k] also requires solely the change of point of articulation, since [k] is velar.

b) Errors with fricatives

There were only three types of errors that subjects made with the voiceless labio-dental fricative sound [f]. Subjects either replaced it with [p], [t] or its voiced counterpart [v]. Replacing [f] with [p] and [v] each occurred a total of two times across subjects. The modification of [f] with [p] means changing two features of the original sound. The subject needed to change both the manner and point of articulation features, due to the fact that [f] is a labio-dental fricative and [p] is a bilabial stop. They only share the feature of voicing, both being voiceless consonants. Changing the original voiceless labio-dental fricative [f] to voiceless denti-alveolar plosive [t] meant changing the two features, manner and place of articulation, and keeping the voicing feature constant. As mentioned earlier, modification of [f] with [v] only requires changing the voicing feature, since the two sounds already share the manner and place of articulation features.

There were only two types of errors that included the denti-alveolar voiceless fricative [s]: substitution of [s] by [f] and [z]. The sounds [s] was replaced with were not very different from itself. Replacing [s] with [f] means changing the point of articulation feature one step to the front since [s] is denti-alveolar and [f] is labio-dental. Replacing [s] with [z], on the other hand was even easier since they already share both manner and point of articulation features, all the subject needed to do was to modify the voicing feature.

The speech errors with the voiced labio-dental fricative [v] fell into five categories; it was replaced by one of these five consonants: [b], [d], [f], [g] or [z]. There are again some common properties between these sounds and the original sound [v]. To start with, [v] and [b] have the common property of being voiced and anterior. But they differ in manner of articulation and the exact place of articulation, since [b] is a bilabial oral stop and [v] is a labio-dental fricative. [v] and [d] also share voicing and differ in manner of articulation since [d] is a denti-alveolar plosive. The most common speech error with the sound [v] was its substitution by [f], which occurred a total of 14 times. This mistake was predictable since the only feature these sounds differ is voicing feature. Another speech error attested with [v] was substitution by [g], which only occurred once. These two sounds only share the state of glottis feature and they differ in manner and point of articulation features. The sound [v] is a labio-dental fricative, whereas, [g] is a velar plosive. The last type of speech error attested with [v] was its replacement by [z]. These two sounds, [v] and [z], only differ in one feature, that is the exact place of articulation. They share the features of voicing and manner of articulation since they are both voiced and fricatives. They also share the feature of being anterior, since both sounds are produced in the front part of the mouth. They only differ in the precise point of articulation since [v] is labio-dental and [z] is denti-alveolar.

The final consonant participating in speech errors was with the voiced denti-alveolar fricative [z]. There were four different sounds that [z] was replaced with. These were: [d], [g], [s] and [v]. Again there are certain common properties among these sounds. First of all, substituting [d] with [z] meant modifying only one property of the original sound, that of manner of articulation. These two sounds already share point of articulation and voicing features, both being denti-alveolar and voiced. They only differ in manner of articulation since [z] is a fricative but [d] is a plosive. The second error with [z], was its substitution by [g]. These two consonants only share one feature, that of being voiced. They differ in manner and place of articulation features since [g] is a velar plosive and [z] is a alveolar fricative. Replacing [z] with its voiced counterpart [s] was the most common speech error attested with [z]. The last type of error were replacing [z] with [v], which required a modification of one feature, that of point of articulation. [z] and [v] already share voicing and manner of articulation features since they are both voiced fricatives.

The following table 18 provides a summary of all the errors made by height disharmony subjects.

Table 18: Overview of the speech errors of height disharmony subjects

Consonant Errors	148
Consonants not read (deletion)	200
Total consonant errors	348
Vowel identity (perseveration + anticipation)	0
Vowel switch errors (exchange)	6
Another Vowel (substitution)	0
Other Vowel Errors	0
Total vowel errors	208
Creating harmony from disharmony	2
Vowels not read (deletion)	200
TOTAL NUMBER OF ERRORS	556

As can be observed from table 18, height disharmony subjects made more errors with consonants when compared to vowels. As has been mentioned when analyzing the actual speech errors of subjects there were certain features shared between the original consonant and the consonant that it was replaced with as a result of speech errors. Most of the speech errors included a consonant being replaced with its counterpart in voicing, keeping other features of point and manner of articulation constant. That is, replacing a voiced consonant with its voiceless counterpart and vice versa. This shows that subjects tend to keep some features of the original sound even in their speech errors.

3.1.2.3. Speech Errors of Mixed Condition Subjects Trained in Height Harmony Condition

As was mentioned in the introduction chapter under the method section, the mixed condition was a combination of harmony and disharmony condition since it included words formed with height harmony rules as well as words formed with height disharmony rules. Thus subjects were trained with both height harmonic and height disharmonic words during their training phase. This means that they were not presented with a coherent pattern as was the case for harmony or disharmony conditions. Since they saw both words from the harmony set and the disharmony set, there was no pattern they could generalize as the phonology of the artificial language system they were presented with. However, this condition was presented to the subjects to analyze how the lack of a consistent harmony or disharmony pattern will affect the subjects' speech errors and their learning the condition. This pattern can also be said to represent such languages where the language itself has a consistent choice in terms of harmony or disharmony but this pattern is disturbed by borrowed words which violate the pattern.

Again the four vowels [i], [e], [u] and [o] were used in the words. Since half of the word sets they saw were adhering height harmony rules, so high vowels were used together in a single word and low vowels were used together as in: *pizu, fego, subi, poze;* and the other half was violating height harmony and adhering to height disharmony since a high vowel was combined with a low vowel in a word as in: *sibo, zovi, bevu, sude.*

3.1.2.3.1. Possible errors

The possible speech errors that mixed group subjects were likely to make were actually a combination of all possible harmony errors and disharmony errors presented in the previous sections, since the system they were presented with includes words from both sets. A new list will not be provided at this point since it is only the combination of the two lists given before.

3.1.2.3.2. Actual Participant Errors

3.1.2.3.2.1. Vowel Errors

The table 19 below provides the errors on the first column along with the category of the errors. So, [o]-[i] stands for a word with [o]-[i] sequence such as *fobi*. Thus, o-i → o-o, illustrates *fobi* being pronounced as *fobo* as a result of speech error. The second column represents the rate of speech errors, that is the number of errors divided by the number of subjects.

Table 19: The list of speech errors in vowels of subjects trained in the mixed condition of height harmony

Vowel errors	**Total**	**Rate**
Repeat 1st V (perseveration)	0	0
Repeat 2nd V (anticipation)		

u-e → e-e	1	0.083
e-o → o-o	1	0.083
o-e → e-e	1	0.083
Switch Vs (exchange)		
u-i → i-u	11	0.91
i-u → u-i	3	0.25
e- o → o- e	5	0.41
o-e → e-o	1	0.083
u-e → e-u	1	0.083
e-u → u-e	1	0.083
i-o → o-i	1	0.083
Creating (height) harmony		
e-u→ e-o	2	0.16
u-e → o-e	5	0.41
e-u→ i-u	1	0.083
u-e→ e-o	1	0.083
u-e→ o-e	1	0.083
u-e→ u-i	1	0.083
i-o→ i-u	7	0.58
o-i → u-i	1	0.083
Creating (height) disharmony		
i-u → o-i	1	0.083
i-u → i-o	12	1
u-i → u-e	1	0.083
u-i → o-i	3	0.25

e-o → e-u	3	0.25
o-e → e-u	1	0.083
o-e → u-e	1	0.083
u-i → e-u	1	0.083
Keeping harmony but changing vowels		
e-o→ u-i	1	0.083
Creating backness harmony from height disharmony		
o-i→ e-i	1	0.083
Keeping disharmony but changing vowels		
i-o → e-u	1	0.083
Another vowel not used in the experiment		
u-i→ ü-u	1	0.083

As can be observed from table 19 above, some errors were more common than others. When we compared these actual errors to the list of all possible errors, we saw that the speech errors of subjects tended to fall into certain categories. It is worth noting that the list of possible errors for mixed height harmony subjects was a combination of harmony errors and disharmony errors.

There were a total of 72 vowel errors, but these errors fell into 30 different categories. 20 of these errors constituted the subject creating harmony from a disharmonic word, of these only one error resulted in backness harmony from a height disharmonic root, all other were creating height harmony from height disharmony. Creating backness harmony from height disharmony required the subject to change a single feature of one vowel, when the subject changed the rounding/ backness feature of [o], he/she would get [e] and the resulting string e-i would be an example of backness harmony.

There were no instances of speech errors where a subject repeated the first vowel (perseveration). There were, however, three instances of anticipation errors, where the subject deleted the first vowel and replaced it with the second vowel. Two of these errors included the height harmonic e-o string and one error included the height disharmonic u-e string. There were more instances of [e] sounds as a result of this type of speech error.

There were 23 switch errors, where the subjects used the same vowels as in the original string but modified their order. Strings which originally had height harmony were more common to be seen in such errors than strings with height disharmony, the ratio being 21/3. Of the strings which originally had height harmony, the pairs that included high vowels were more likely to participate in switching errors than pairs with low vowels, the ratio being 14/6. The most common error attested in this type was to replace u-i string with i-u string, occurring a total of 11 times. The second and third most common errors after u-i were e-o and i-u, respectively.

Of the other speech errors where the subject created height harmony from height disharmony, the most common error was changing the i-o string to i-u. For this error, the subject needed to change only the backness feature of the second vowel, and the resulting combination i-u confirmed to height harmony. There was also an instance of one subject changing the o-i string to u-i, which was the same type of error. There were actually more instances of errors where the subjects modified the e-u string (in either order) to get a height harmonic result. There were a total of 13 errors of this type, as can also be observed from the table above. Of these, the most common error was to change the u-e string to o-e, which occurred a total of 5 times.

There were also speech errors where the subjects changed the vowels to that a height harmonic string ended up to have height disharmony. There were a total of 23 errors of this type. Of these the most common was to change the i-u string to i-o string, which occurred a total of 12 times. This error only required a modification of a single feature of the second vowel, but the result is disharmonic in terms of height harmony since [i] and [o] have different features for height. In total, there were 5 instances of errors with i-u string (in either order) and 3 errors with e-o string (in either order). When the subjects made a speech error with i-u string, it was more common for them to create a o-i string as a result than a u-e string (16/ 2). The reason for this may be that they had more tendency to change [u] to [o].

There was only one instance where a subject used another vowel than the four vowels used in the experiment as a result of speech error. In this single case, the subject used [ü] instead of the high back rounded vowel [u].

It is also interesting to note the single error where the subject kept the height harmony even though he/she changed both of the vowels. In this error, the subject modified the original e-o string and replaced it with u-i. Two features of each vowel had to be modified by the subject for this error, since the vowels differ from each other both in backness/ rounding and height properties. Changing the i-o string to e-u is also similar to this error since the subject again changed two features of both vowels. However, in this second instance the subject kept height disharmony even in the speech error.

3.1.2.3.2.2. Consonant Errors

The following table 20 provides a complete list of all the speech errors conducted by height harmony mixed condition subjects. The total number of any error across subjects and the rate of any error can also be observed from the table, by the second and third columns, respectively.

Table 20: Consonant errors by height harmony mixed condition subjects

Consonant errors	**Total Errors**	**Rate**
b → d	7	0.58
b → g	3	0.25
b → k	1	0.083
b → p	2	0.16
b → v	1	0.083
b → z	1	0.083
d → b	2	0.16
d → g	5	0.41
d → v	4	0.33
d → z	2	0.16
g → d	3	0.25
g → k	2	0.16
g → v	3	0.25
g → z	1	0.083
k → p	1	0.083
p → b	2	0.16
p → f	1	0.083
p → k	1	0.083
p → v	1	0.083
s → z	8	0.66
t → d	1	0.083
v → b	2	0.16
v → d	5	0.41
v → f	2	0.16
v → g	2	0.16
z→ d	3	0.25
z → g	6	0.5
z → v	1	0.083

When the speech errors of subjects trained in the height mixed condition were analyzed, it was seen that the errors fall into certain patterns. There were a total of 28 different types of errors, but as with the case for the errors of subjects from other conditions some errors were more common than others. First of all, there was a different pattern observed in the speech errors of subjects in the mixed height harmony condition. As observed in most of the other conditions, the most common error for most of the consonants was to change the voicing feature of the consonant, while keeping the place and manner of articulation constant. However, this was only the most common error attested with consonants [p], [s] and [t]. With all other consonant errors, other errors were more common than voicing errors.

a) Errors with plosives

To start with, the most common error with the voiced bilabial plosive sound [b] was to replace it with the voiced denti-alveolar plosive [d], which occurred a total of 7 times across subjects. For this error, the subject had to change only the point of articulation of the original consonant since [b] and [d] already share the features of state of glottis and manner of articulation. The other errors with the [b] included replacement by [g], [k], [p], [v] and [z]. Among these errors, the most common was replacing [b] with [g], which occurred a total of 3 times. A subject who made this error had to change the point of articulation of the original consonant. The other features of the original consonant did not need to be modified since [b] is already a voiced plosive like [g]. They only differ in their point of articulation since [g] is a velar sound. Changing [b] to [k], however, needed a modification of two features since [k] is both velar and voiceless, differing from [b] in both. There were only a total of two instances where a subject changed [b] into its voiceless counterpart [p], although this was the easiest error to make since [p] and [b] only differ in voicing. There was one instance where a subject modified [b] with the voiced labio-dental fricative [v]. The sounds [b] and [v] share the feature of being voiced and being anterior. However, their point of articulation is not exactly the same since [b] is bilabial and [v] is labio-dental. They also differ in their manner of articulation since [b] is a plosive sound, which is produced with an egressive pulmonic air stream mechanism. [v], on the other hand, is a fricative since it is produced with partial obstruction of the air flow such that air moving through the articulators results in audible friction. The final type of error with [b] was its replacement by [z], which is a voiced denti- alveolar fricative. Changing [b] into [z] required a modification of both the manner and point of articulation. They only share the feature of being voiced.

The speech errors with the voiced denti-alveolar plosive [d] fall into four categories: [b], [g], [v] and [z]. The most common of these errors was replacing [d] with the voiced velar plosive [g], occurring a total of five times across subjects. This error meant that the subject had to modify only the exact point of articulation of the original vowel, since [d] and [g] already share their manner of articulation and voicing features. Replacing [d] with its voiceless counterpart [t] was not an error attested in this condition by any of the subjects. Replacing [d] with [b] required a change of the point of articulation of the original consonant [d], since it is a denti-alveolar sound and [b] is a bilabial sound, produced with bringing the upper and lower lips together. Another error with [d] was to replace it with the voiced labio-dental fricative [v]. This error resulted by changing two features of the original consonant [d]: the manner and the point of articulation. The final error with [d] was to replace it with the voiced denti-alveolar fricative [z]. These two sounds have the same value for voicing and the point of articulation, but they differ in the manner of articulation: [d] is an oral stop, whereas [z] is a fricative.

Other speech errors which were made by height harmony mixed subjects included errors with the consonants [g], [k], [p], [s], [t], [v] and [z]. To begin with, there were four different types of errors with the consonant [g]. The first type of error with the voiced velar plosive [g] was to replace it with [d], which occured a total of three times. This error meant that the point of articulation of the original consonant [g] was modified, since [d] is denti- alveolar. Other than this, [g] and [d] already share the properties of being voiced and being plosives. The second type of error with the consonant [g] was replacing it with its voiced counterpart [k], occurring a total of two times. These two sounds have the same manner and point of articulation yet differ in terms of voicing properties, [g] being voiced and [k] voiceless. Another error conducted by height harmony mixed subjects concerning the consonant [g] was to modify it with [v], which occurred three times. This error required that the original consonant be modified for both manner and place of articulation. Whereas [v] is a labio-dental fricative; [g] is a velar plosive so they only share the feature of voicing. The final error concerning [g] was its substitution by the voiced denti-alveolar fricative [z]. The sounds [g] and [z] also have the single feature of voicing in common and differ in manner and place of articulation.

There was only one error with the voiceless velar plosive [k] and it included its replacement by the voiceless bilabial plosive [p]. This error required a modification of only a single feature, that of point of articulation. [p] and [k] already share the property of being plosive and being voiceless.

When it comes to the voiceless bilabial plosive [p], it was observed that this sound was replaced with four different consonants: [b], [f], [k] and [v]. The first error, that is [p] being replaced with [b], was the most common error, as was stated before. This simply required changing the voicing feature of the original sound. The second error was to replace [p] with [f]. This error required to change two features of the original consonant: the manner and place of articulation, since [f] is a labio-dental fricative. The state of glottis feature did not need to be changed since both [f] and [p] are voiceless. Another error with [p] included its substitution by [k], which is a voiceless velar plosive. Changing [p] to [k] required only changing the point of articulation. The final error with the consonant [p] was its modification to the voiced labio-dental fricative [v]. This was the error which included a change in all three features, since [p] and [v] only share the feature of being anterior. They differ in manner and place of articulation and voicing. [v] is a voiced labio-dental fricative whereas [p] is a voiceless bilabial plosive.

There was also a single kind of error height harmony mixed subjects made with the consonant [t], this was also the same type of error since [t] was replaced by its voiced counterpart [d]. The sounds [t] and [d] already share the same features for manner and point of articulation since they are both denti-alveolar plosives.

b) Errors with fricatives

There was only a single type of error with the voiceless denti-alveolar fricative [s], but this can be considered as a common error since it occurred a total of 8 times across subjects. This error was changing [s] into its voiced counterpart [z]. This error is very predictable since all the subject needed to modify is the state of glottis feature, as the two sounds already share the manner and point of articulation.

The speech errors subjects made with the voiced labio-dental fricative [v] consisted of four types: its substitution by [b], [d], [f] or [g]. The first error, that is [v] being replaced by [b] requires a change of two features: manner and point of articulation. Voicing feature does not need to be modified since both are already voiced. However, since [b] is a bilabial plosive, the other two features need to be modified. The second and the most common type of error with [v] was its being modified by [d], occurring a total of five times. This error also required changing all two features but voicing. Although they are both anterior consonants, they differ in the exact place of articulation since [v] is labio-dental and [d] is denti-alveolar. They also differ in the manner of articulation since [v] is a fricative and [d] is a plosive. The third error with [v] included its substitution by [f], which occurred two times. This error was the most predictable error since it simply required a change of the voicing feature of the original consonant. The final error with [v] was its modification into a voiced velar plosive, which is [g]. These two sounds only share the feature of being voiced. So, the subject who replaced [v] with [g] needed to modify the manner and place of articulation features of the original vowel.

The final consonant sound participating in speech errors was the voiced denti-alveolar fricative [z]. There were three different types of errors that this sound participated in. These were its substitution by [d], [g] or [v]. Although these sounds share common properties with the original sound, there are also obvious differences. The first error, that is replacing [z] with [d] required a modification of only one feature of the original sound. [z] and [d] are both voiced and denti-alveolar, the subject did not need to change that, but he/she needed to change the manner of articulation to get the plosive [d]. The second error was [z] being replaced by the voiced velar plosive [g]. These two sounds only share the feature of being voiced. They, however, completely differ in manner and point of articulation. [g] is produced further back in the mouth since it is a velar sound. [g] is also produced with the egressive pulmonic air stream, since it is a plosive. The original sound [z], on the other hand, is produced with a partial obstruction of the airflow such that air flowing through the articulators result in audible friction, since it is a fricative. The final sound that participated in speech error with [z] was the sound [v]. This speech error required a modification of only the point of articulation of the original sound. The two sounds are both anterior sounds, but [z] is denti-alveolar whereas [v] is labio-dental.

The following table 21 provides a summary of all the speech errors conducted by the height harmony mixed condition subjects.

Table 21: Overview of the speech errors of height harmony mixed condition subjects

Consonant Errors	117
Consonants not read (deletion)	336
Total consonant errors	453
Vowel identity (perseveration + anticipation)	3
Vowel switch errors (exchange)	23
Another Vowel (substitution)	1
Other Vowel Errors	0
Total vowel errors	408
Creating harmony from disharmony	19
Creating disharmony from harmony	23
Creating backness harmony from height disharmony	1
Vowels not read (deletion)	336
TOTAL NUMBER OF ERRORS	861

3.1.2.4. Comparison of common patterns among the three conditions in height harmony

A closer look at the speech errors conducted by subjects in three different conditions of the height harmony revealed that there were indeed both common and different patterns among their errors. To begin with, whereas height harmony subjects made two errors that resulted in vowel identity, height disharmony subjects did not make any errors of this type. This supported the initial assumption that height disharmony subjects are already aware that the two vowels in the word were different from each other. Another finding that reinforced this was the data from height harmony mixed subjects. There were three instances where height mixed subjects created vowel identity and two of these instances were originally height harmonic items.

Another interesting finding that results from the comparison of three groups is that there were more switch errors made by harmony subjects. Height harmony subjects made 15 errors that include switching places of the two vowels in the word whereas disharmony subjects made 6 errors of this type. Mixed harmony subjects made 23 errors of this type and 20 of these errors were from harmonic roots, which also support the claim that harmony subjects made more switching errors where they kept harmony.

There were 5 instances where harmony subjects violated height harmony; but none of these resulted in backness harmony. Disharmony subjects made 2 speech errors where they violated disharmony and both errors resulted in harmony. As can be remembered from the previous section, height harmony mixed subjects made errors both resulting in harmony and disharmony.

A closer look at the consonant errors also revealed some common patterns among the three groups. First of all, height harmony subjects made more errors with the voiced consonants, including both the fricatives and the plosives. The consonant that led to the highest number of errors was the voiced labio-dental fricative [v], with a total of 19 errors. This was followed by the voiced bilabial plosive [b], with a total of 16 errors. Subjects did not make any errors with the voiceless denti-alveolar plosive [t]. The errors with plosives and fricatives were identical in number, 31 and 31, respectively. There was also a similar pattern in the speech errors of height disharmony subjects in that they also made more errors with the voiced consonants. The most problematic consonants were [v] and [b], with 22 and 17 errors respectively. The only difference between harmony and disharmony subjects was that disharmony subjects made more errors with plosives, whereas the numbers were very close to each other for height harmony subjects. Height harmony mixed condition subjects also made more errors with the voiced consonants. For them the most problematic consonants were [b], [d], [v] and [z], with 15, 13, 11 and 12 total number of errors, respectively. Subjects in this group also made more errors with plosives than they did with fricatives, 53 and 31 respectively.

3.1.3. General Discussion of the speech errors in backness and height harmony groups

The errors of all subjects actually pointed to some patterns in this artificial language system. First of all, consonants were more prone to speech errors than vowels. This may be due to the fact that subjects were aware of the patterns of vowels in the different conditions they saw. The consonants did not have an effect on the learning of the system.

Mixed harmony subjects in both conditions did more vowel errors than other subjects, which pointed out to the difficulty caused by the lack of pattern. Both harmony and disharmony subjects performed better than mixed group subjects. This points out to the fact that even if the system subjects were trained on is not similar to their native language, it was still easier than lack of any system. Because there was no system in the mixed condition since it was a combination of both harmony and disharmony words, it was confusing for the subjects.

Among the consonants there were also common patterns, subjects in all 6 groups made more speech errors with voiced consonants when compared to voiceless consonants. Subjects from most of the groups made more speech errors with plosives. The reason for this may be that the production of plosives required more phonetic effort than fricatives.

The CVCV pattern of the artificial language system used in the experiment may also have had an effect on the consonant errors. The consonants that the subjects produced were always next to vowels due to the characteristic of the artificial system. It is also known from natural languages that vowels have an effect in the surrounding consonants. Wilson (2007) found that post- velar consonants have an effect on vowels in Nuuchahnulth. Coleman (1994) and Koenig & Fuchs (2007) can also be referred to as some of the many studies showing the effect of vowels on the neighboring consonants in natural languages. This effect of vowels coupled with the time constraint on the production in the experiment may be the reason of consonant errors.

It also seems that the first vowel had precedence; subjects got it right at the expense of the second one. This finding is actually very crucial because in the speech errors literature (see Dell et al, 2000) it was found there is a tendency for errors to be anticipatory, which would give second vowel precedence. The reason for these seemingly contradictory results may be due to the fact that vowel errors and consonant errors show a different pattern.

Backness harmony subjects were more likely to maintain the rules of the conditions they are trained on even in their speech errors. There was only a single error where a backness harmony subject violated harmony. The reason for this may be that backness harmony is simpler. Since by definition the back vowels used in the experiment were round, backness harmony also meant rounding harmony. This meant that vowels in the same word agreed in both backness/frontness and rounding features. Furthermore, backness harmony was closer to the harmony attested in Turkish. Since all the subjects in the experiment spoke Turkish as their native language this might have had an effect on their speech errors. Because backness harmony condition was similar to harmony in Turkish this might ease their speech production. These results also support previous studies that backness harmony is more basic and typologically more common than height harmony and whereas backness harmony facilitates production height harmony does not (Linebaugh, 2007).

3.2. ANALYSIS AND DISCUSSION FOR THE TEST PHASE

As was discussed in the previous chapters, subjects were asked to choose between two words in the test phase. One of the words was constructed so that it obeys the condition they were trained on and the other word violated the condition. That is, if a subject was trained on backness harmony condition, then one of the two words she/he saw would have backness harmony and the other word violated the harmony. Her/his choosing the word containing harmonic sounds thus meant that s/he learnt the rules of the condition he was trained on, since the only difference between the two words was one being harmonic and the other disharmonic. For the test phase, planned comparisons were conducted to compare both the harmony and the disharmony conditions against the mixed baseline. Mixed condition eliminated the effect of training and was used to show whether subjects had any bias towards harmony or disharmony. Since there was no coherent pattern that the subjects saw in the mixed condition, choosing harmony or disharmony would show their bias.

3.2.1. Backness Harmony

Since subjects trained in the backness harmony condition saw words having either backness harmony or backness disharmony, the test items were constructed so that one of the words violated backness harmony and the other conformed to it. To illustrate, *buzo* and *debu* were an actual pair that the subjects in all three conditions saw. Harmony subjects were expected to choose *buzo* since it had vowel harmony like the other words they saw in the training phase. Disharmony subjects, on the other hand, were expected to choose *debu* since the vowels were disharmonic and they were trained on such words with disharmony. Mixed subjects saw words both from the harmony set and the disharmony set, so their choice would show whether they have bias towards one condition. It is worth reminding at this point that none of the words in the test words were the words they actually saw on their training phase, they were only words constructed with the same rules as the other words they saw.

There were 12 subjects in each condition and each subject saw 10 pairs of words and the order of words was again randomized for each subject.

3.2.1.1. Harmony condition

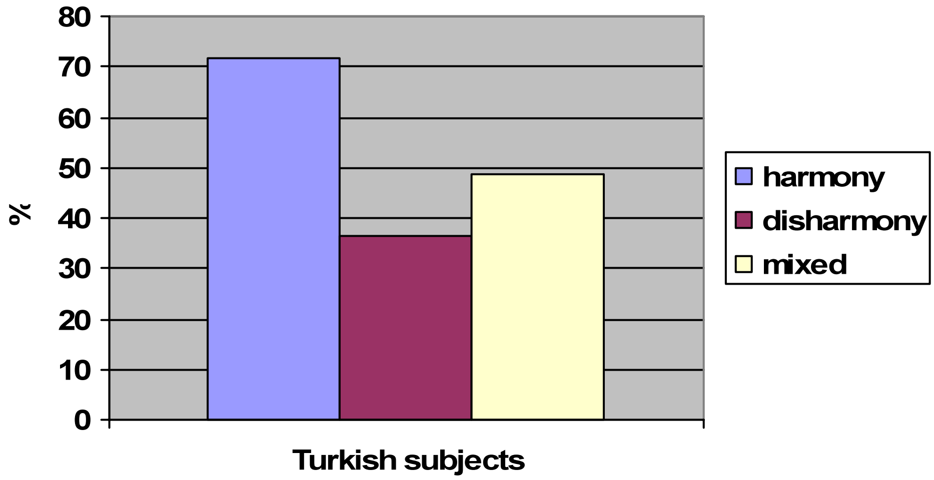
As the following graph 1 indicates, harmony subjects chose harmony 14.3 times out of 20 items (71.5%). This showed that they preferred harmony over disharmony since their training had vowel harmony as well. If they chose harmony only 10 times out of 20, then this could be interpreted as chance or as not having learnt the condition they were trained on. However, this preference towards harmony showed that they learnt that the words they were trained on had vowel harmony and they chose the words having the same kind of pattern.

3.2.1.2. Disharmony condition

The average mean of disharmony subjects choosing the word with harmony was 7.25 times out of 20 items (36.25%), as can be observed from the table below. This meant that, they chose disharmony at an average of 12.75 out of 20 items. This again showed the subjects' preference towards the condition they were trained on.

3.2.1.3. Mixed condition

Mixed condition subjects chose harmony 9.75 times out of 20 items (48.75%). That is, they chose the word with disharmony at an average of 10.25 words out of 20 words. This showed that they did not have a preference towards any of the condition, since the mean of mixed subjects is close to that of chance. Because if they chose according to chance, they would pick words with harmony 10 out of 20 times, and the actual results were very close to that.



Graph 1: Comparison of results in different conditions for backness harmony subjects

As can be observed from the Graph 1 above, Turkish subjects seemed to learn the backness vowel harmony condition they were presented with. It is also noteworthy that Turkish subjects did not have a preference for harmony when they were not presented with a consistent pattern, as illustrated from the responses of subjects trained in mixed harmony condition. It can also be said that Turkish subjects trained on vowel disharmony learnt the condition they were trained on, as indicated from their choice of harmony in the test condition.

Kruskal-Wallis test was used to test whether there were significant differences between the three groups trained in the backness harmony condition. This test compares the difference between mean ranks and the medians of the results of each group. It evaluates whether the population medians on a dependent variable are the same across all levels of a factor. With the K independent samples test, Kruskal-Wallis test, a chi-square statistic is used to evaluate the differences in mean ranks to assess the null hypothesis that the medians are equal among groups.

The results of the Kruskal- Wallis test revealed that the results were significant, as can be observed from the table 23 below (Asymp. Sign <.05)

Table 22: Mean ranks of subjects in three conditions of backness harmony

Ranks

	group2	N	Mean Rank
score	Harmony	12	29,71
	Disharmony	12	9,58
	Mixed	12	16,21
	Total	36	

Table 23: The results of the Kruskal- Wallis test

Test Statistics[a,b]

	score
Chi-Square	22,942
df	2
Asymp. Sig.	,000

a. Kruskal Wallis Test

b. Grouping Variable: group2

Additional statistical tests were also conducted to see whether there was also a difference between groups when the groups were compared to the each other in groups of two. For this aim, the non-parametric, two independent samples test Mann-Whitney-U test was conducted. The Mann-Whitney-U test evaluated whether the medians on attest variable differed significantly between two groups[4]. Mann-Whitney-U test was used so that groups were compared to each other in two-way comparisons.

The results of the Mann-Whitney-U test showed that the difference between backness harmony and backness disharmony groups were significant, as can be observed from the tables below[5].

[4] In the SPSS data file each case must have scores on two variables, the independent (grouping) variable and the dependent (test) variable. The independent variable divides cases into two groups or categories and the dependent (test) variable assesses individuals on a variable with at least an ordinal scale. For a Mann-Whitney-U test, the scores on the test variable are converted into ranks, ignoring group membership. The test then evaluates whether the mean ranks for the two groups differ significantly from each other. To the extent that the population distributions differ, the test does not evaluate whether the medians differ between populations, but only whether the distributions themselves differ.

[5] Two p-values (asymp. and exact significance) are reported, an exact two tailed p, which is not corrected for ties and a two tailed p which is based on the z-approximation test and corrected for ties. As is typically the case, the difference between the two p-values is negligible.

Table 24: Mean ranks and sum ranks of subjects in backness harmony and backness disharmony conditions

Ranks

	group2	N	Mean Rank	Sum of Ranks
score	Harmony	12	18,25	219,00
	Disharmony	12	6,75	81,00
	Total	24		

Table 25: The results of the Mann-Whitney-U test for backness harmony and disharmony subjects

Test Statistics[b]

	score
Mann-Whitney U	3,000
Wilcoxon W	81,000
Z	-4,002
Asymp. Sig. (2-tailed)	,000
Exact Sig. [2*(1-tailed Sig.)]	,000[a]

a. Not corrected for ties.

b. Grouping Variable: group2

The comparison of the differences between disharmony and the mixed groups however, did not reach significance[6].

Table 26: Mean ranks and sum ranks of subjects in backness disharmony and mixed subjects

Ranks

	group2	N	Mean Rank	Sum of Ranks
score	Disharmony	12	9,33	112,00
	Mixed	12	15,67	188,00
	Total	24		

[6] Again as can be observed from table 27, two *p*-values are reported, an exact two tailed *p*, which is not corrected for ties and a two tailed *p* which is based on the *z*-approximation test and corrected for ties. As is typically the case, the difference between the two *p*-values is negligible.

Table 27: The results of the Mann-Whitney-U test for backness disharmony and mixed subjects

Test Statistics[b]

	score
Mann-Whitney U	34,000
Wilcoxon W	112,000
Z	-2,217
Asymp. Sig. (2-tailed)	,027
Exact Sig. [2*(1-tailed Sig.)]	,028[a]

a. Not corrected for ties.

b. Grouping Variable: group2

A comparison of backness harmony and the backness mixed group, on the other hand, provided significant results, as table 29 clearly illustrates[7].

Table 28: Mean ranks and sum ranks of subjects in backness harmony and backness mixed conditions

Ranks

	group2	N	Mean Rank	Sum of Ranks
score	Harmony	12	17,96	215,50
	Mixed	12	7,04	84,50
	Total	24		

Table 29: The results of the Mann-Whitney-U test for backness harmony and mixed subjects

Test Statistics[b]

	score
Mann-Whitney U	6,500
Wilcoxon W	84,500
Z	-3,803
Asymp. Sig. (2-tailed)	,000
Exact Sig. [2*(1-tailed Sig.)]	,000[a]

a. Not corrected for ties.

b. Grouping Variable: group2

[7] Both of the two *p*-values reported, an exact two tailed *p*, which is not corrected for ties and a two tailed *p* which is based on the *z*-approximation test and corrected for ties, denote significance.

To sum up, statistical analysis revealed that the difference between the mean ranks and the medians of the three different groups trained in the backness harmony condition was significant. Also, the difference between harmony and mixed, harmony and disharmony groups were significant.

3.2.1. Height Harmony

Test phase for the height harmony subjects were identical to that of backness harmony subjects. The only difference was the vowels in the words they saw. They saw word pairs such as *bivu gezu*, where one of the words had height harmony and the other did not. The logic behind the test phase was exactly the same: if the subject was trained on height harmony he/she was expected to choose the word with harmony and vice versa. Mixed condition was again used to see any possible bias towards harmony or disharmony.

3.2.1.1. Harmony Condition

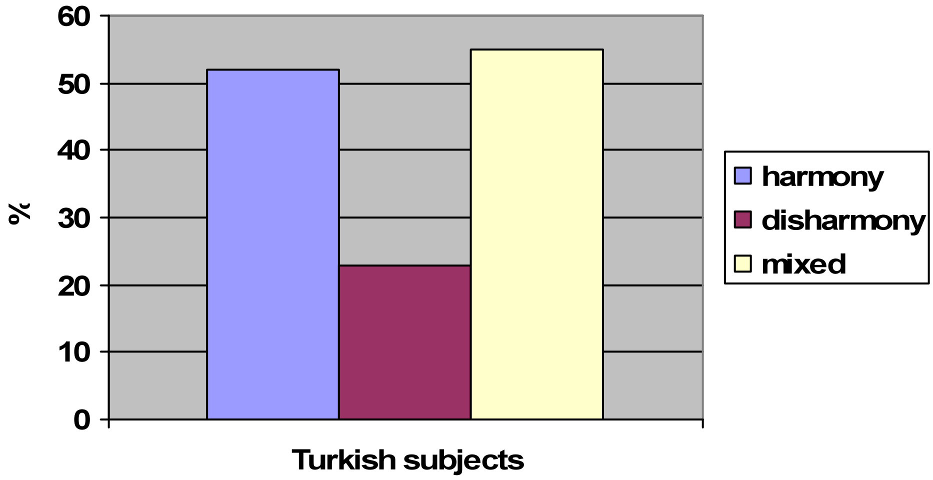
Height harmony subjects chose harmony 10.41 times out of 20 items (52.05). That is, the average mean of harmony subjects choosing the word with height harmony was very close to chance.

3.2.1.2. Disharmony Condition

The average mean of height disharmony subjects choosing the word with harmony was 7.58 times out of 20 items (22.9%). What this meant was that, height disharmony subjects chose the word that was similar to the condition they were trained on was 12.42. This was higher than the rate of pure chance.

3.2.1.3. Mixed Condition

Height harmony mixed condition subjects chose harmony 11 times out of 20 items (55%). That is, they chose the word with disharmony at an average of 9 times out of 20 items, which showed a bias towards harmony.



Graph 2: Comparison of results for height harmony subjects trained in different conditions

Kruskal-Wallis test was also conducted on the results of the subjects trained in the three different conditions of height harmony to see whether the difference between the mean ranks and the medians of the groups were statistically significant or not. As stated before, this test compared the difference between mean ranks and the medians of the results of each group. It evaluated whether the population medians on a dependent variable are the same across all levels of a factor. With the K independent samples test, Kruskal-Wallis test, a chi-square statistic is used to evaluate the differences in mean ranks to assess the null hypothesis that the medians are equal among groups.

The results of the non parametric analysis, Kruskal- Wallis test, as can be observed from table 31 below, revealed that the results are not significant, as can be observed from the output tables below (Asymp. Significance >.05).

Table 30: Mean ranks of subjects in three conditions in height harmony

Ranks

	group2	N	Mean Rank
score	Height Harmony	12	21,58
	Height Disharmony	12	11,54
	Height Mixed	12	22,38
	Total	36	

Table 31: The results of the Kruskal- Wallis test

Test Statistics[a,b]

	score
Chi-Square	7,958
df	2
Asymp. Sig.	,019

a. Kruskal Wallis Test

b. Grouping Variable: group2

Then the results were again compared by using a different non-parametric test, that of Mann-Whitney-U test so that groups were compared to each other in two-way comparisons. The Mann-Whitney-U test evaluates whether the medians on a certain test variable differ significantly between two groups[8]. The results of the Mann-Whitney-U test showed that the difference between height harmony and height disharmony groups did not reach significance, as can be observed from the tables 32 and 33 below.

Table 32: Mean ranks and sum ranks of subjects in height harmony and height disharmony conditions

Ranks

	group2	N	Mean Rank	Sum of Ranks
score	Height Harmony	12	15,58	187,00
	Height Disharmony	12	9,42	113,00
	Total	24		

[8] The SPSS data file each case must have scores on two variables, the independent (grouping) variable and the dependent (test) variable. The independent variable divides cases into two groups or categories and the dependent (test) variable assesses individuals on a variable with at least an ordinal scale. For a Mann-Whitney-U test, the scores on the test variable are converted into ranks, ignoring group membership. The test then evaluates whether the mean ranks for the two groups differ significantly from each other. To the extent that the population distributions differ, the test does not evaluate whether the medians differ between populations, but only whether the distributions themselves differ.

Table 33: The results of the Mann-Whitney-U test for height harmony and disharmony subjects

Test Statistics[b]

	score
Mann-Whitney U	35,000
Wilcoxon W	113,000
Z	-2,148
Asymp. Sig. (2-tailed)	,032
Exact Sig. [2*(1-tailed Sig.)]	,033[a]

a. Not corrected for ties.

b. Grouping Variable: group2

The difference between the two groups, height disharmony and mixed group did not reach significance either, although the results were close to significant as can be observed from the tables 34 and 35 below.

Table 34: Mean ranks and sum ranks of subjects in height disharmony and height mixed conditions

Ranks

	group2	N	Mean Rank	Sum of Ranks
score	Height Disharmony	12	8,63	103,50
	Height Mixed	12	16,38	196,50
	Total	24		

Table 35: The results of the Mann-Whitney-U test for height disharmony and height mixed conditions

Test Statistics[b]

	score
Mann-Whitney U	25,500
Wilcoxon W	103,500
Z	-2,706
Asymp. Sig. (2-tailed)	,007
Exact Sig. [2*(1-tailed Sig.)]	,006[a]

a. Not corrected for ties.

b. Grouping Variable: group2

The difference between the height harmony and height mixed groups turned out to be not significant either, as can be observed from tables 36 and 37 below:

Table 36: Mean ranks and sum ranks of subjects in height harmony and height mixed conditions

Ranks

	group2	N	Mean Rank	Sum of Ranks
score	Height Harmony	12	12,50	150,00
	Height Mixed	12	12,50	150,00
	Total	24		

Table 37: The results of the Mann-Whitney-U test for height harmony and height mixed conditions

Test Statistics[b]

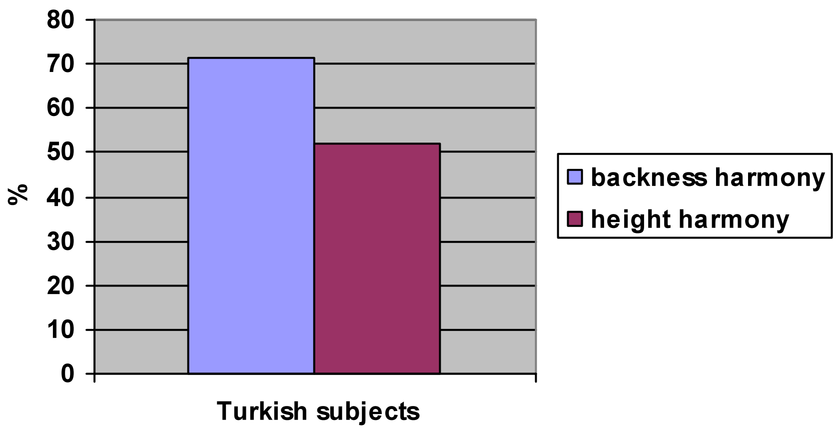
	score
Mann-Whitney U	72,000
Wilcoxon W	150,000
Z	,000
Asymp. Sig. (2-tailed)	1,000
Exact Sig. [2*(1-tailed Sig.)]	1,000[a]

a. Not corrected for ties.

b. Grouping Variable: group2

In short, statistical analysis of the difference between the results of three groups trained in height harmony did not reveal significant results.

As can be observed from the graph 3 below, Turkish subjects performed better with backness harmony compared to height harmony. The average rate of choosing harmony in backness harmony was 71.50% compared to 52.05% in height harmony.



Graph 3: Comparison of results for backness and height harmony subjects

Additional statistical analysis was conducted to see whether being trained on backness or height harmony yielded significant differences in the results. Mann-Whitney-U test was conducted again to compare the median and mean ranks of the groups two by two. In order to achieve this, harmony subjects from backness and height harmony were compared to each other, the results showed no significance, although close, as can be seen from the tables 38 and 39 below.

Table 38: Mean ranks and sum ranks of subjects in backness harmony and height harmony subjects

Ranks

	group2	N	Mean Rank	Sum of Ranks
score	Harmony	12	16,29	195,50
	Height Harmony	12	8,71	104,50
	Total	24		

Table 39: The results of the Mann-Whitney-U test for backness harmony and height harmony subjects

Test Statistics[b]

	score
Mann-Whitney U	26,500
Wilcoxon W	104,500
Z	-2,651
Asymp. Sig. (2-tailed)	,008
Exact Sig. [2*(1-tailed Sig.)]	,007[a]

a. Not corrected for ties.

b. Grouping Variable: group2

As can be seen from tables 40 and 41 below, a comparison of the results of disharmony subjects from two different conditions did not reveal any significant results either.

Table 40: Mean ranks and sum ranks of subjects in backness disharmony and height disharmony subjects

Ranks

	group2	N	Mean Rank	Sum of Ranks
score	Disharmony	12	12,25	147,00
	Height Disharmony	12	12,75	153,00
	Total	24		

Table 41: The results of the Mann-Whitney-U test for backness disharmony and height harmony subjects

Test Statistics[b]

	score
Mann-Whitney U	69,000
Wilcoxon W	147,000
Z	-,177
Asymp. Sig. (2-tailed)	,859
Exact Sig. [2*(1-tailed Sig.)]	,887[a]

a. Not corrected for ties.

b. Grouping Variable: group2

As can be sen from tables 42 and 43, the difference between subjects trained in backness mixed condition and height harmony mixed condition did not reveal significant results.

Table 42: Mean ranks and sum ranks of subjects in backness mixed and height mixed conditions

Ranks

	group2	N	Mean Rank	Sum of Ranks
score	Mixed	12	11,29	135,50
	Height Mixed	12	13,71	164,50
	Total	24		

Table 43: The results of the Mann-Whitney-U test for backness mixed and height mixed conditions

Test Statistics[b]

	score
Mann-Whitney U	57,500
Wilcoxon W	135,500
Z	-,846
Asymp. Sig. (2-tailed)	,397
Exact Sig. [2*(1-tailed Sig.)]	,410[a]

a. Not corrected for ties.

b. Grouping Variable: group2

These additional analysis suggested that there was not a big difference between the performance of subjects trained in the same paradigm (harmony, disharmony or mixed) of the two different systems (backness and height harmony).

3.2.3. General Discussion of the Test Phase

The results of the test phase clearly showed the different performances of the subjects trained in different conditions of backness and height harmony. All subjects in three different conditions of the backness harmony were presented with the same list in the test phase; and all three groups of subjects in the height harmony condition were presented with the same list. So, the only effect in their choise was the training they received. Their different answers clearly indicated that the training phase had an effect.

The results indicated that the subjects who performed best are the backness harmony subjects trained in the harmony condition. There might be more than a single reason for this. First of all, as vowel harmony helps speech segmentation (Vroomen et al, 1998) this experiment showed that it can also be a clue for learning. It seems that Turkish speakers used this clue in learning the artificial language system. Secondly, the harmony condition of the backness harmony was the condition that was closest to Turkish, which was the native language of all the subjects. This similarity might have a positive effect on learning the system.

The results for the mixed condition of both backness harmony and height harmony showed that without the affect of training the subjects had more preference for the harmony items. This also pointed out to the fact that a harmony system is easier to learn compared to a disharmony system. Since mixed condition consisted of items from harmony and disharmony items, the finding that subjects had a bias towards harmony showed the subjects’ preference to harmony. The results clearly pointed to this bias since subjects who saw words from both sets remembered harmony words more than disharmony words in both conditions.

In short, the test phase demonstrated that Turkish subjects learned harmony easier than disharmony, especially in the backness harmony condition.

3.1. ANALYSIS AND DISCUSSION FOR THE WORDS REMEMBERED

In this section, subjects were asked to write down a few words they saw in the training phase of the experiment in order to analyze whether the words they remembered adhere to the condition they are trained on. Since all words were non-sense words which were not parts of the lexicon of Turkish, the words subjects wrote down reflected the condition they were trained on. The number of words each subject wrote down differed from subject to subject, since they were not given a minimum or maximum limit of words they should write down. Then, these lists were analyzed by conditions to see whether there was a certain pattern that subjects use according to the condition they were trained on.

3.3.1. Words Remembered by Backness Harmony Subjects

When the words that the subjects trained on backness harmony remembered were analyzed, it was discovered that the words subjects remember adhered to the condition they were trained on most of the time.

3.3.1.1. Words remembered by subjects trained in Harmony Condition of Backness Harmony

The total number of words remembered by the subjects trained on backness harmony was 70. Of these words they remembered 60% were actual words from the experiment. Out of these 70 words, none of the words violated backness harmony. Only one of the subjects wrote down the items *puva* and *guva* which were not exactly similar to the words they saw, since [a] was not one of the 4 vowels used in the items. However, it should be noted that the items *puva* and *guva* still adhere to backness harmony. 39 of the 70 words, that is 55.71 %, remembered had [i] and [e] (in either order) combination;

and 29 of the words (41.42%) had [o]- [u] combination (either with [o] following [u] or vice versa).

As can be seen from the table 44 below, subjects in backness harmony condition remembered words that had u-o string more than other words. This is followed by i-e string.

Table 44: The strings and the percentages of words remembered by backness harmony subjects

Vowels in the words remembered	**Percentages**
i-e	17.7%
e-i	24.4%
o-u	20%
u-o	31.1%

Table 45 below shows the distributions with the actual words they remembered in detail:

Table 45: The distributions of words remembered by backness harmony subjects[9]

	[e]- [i]	[i]- [e]	[o]- [u]	[u]- [o]	Others
Words remembered by Backness Harmony subjects	***pebi***, *kevi*, ***kedi, bezi, kezi***, ***sebi, devi,*** *sevi*, ***tezi***, *vebi*, ***debi***	***vibe***, ***fide, bide***, ***kive, give***, ***dive, pive***, ***pide, side***, ***zibe, dige***	***povu, dobu***, ***tobu***, ***zovu***, ***fogu***, ***gozu***, ***sogu***, ***sovu***, ***zobu***	***puvo***, ***dugo***, ***puzo***, ***tuzo***, ***kuvo***, ***sudo***, ***pubo***, ***guvo***, ***tugo***, ***pugo,*** ***sugo***, ***pudo***, ***pugo***, ***zubo***	*puva, guba, guvu*
Number of actual words	8 words	11 words	9 words	14 words	0 words
Total	21 words	16 words	12 words	15 words	3 words

9 The words in bold indicate that the word was one of the actual words the subjects saw.

As can be observed from the table 45 above, although subjects remembered words with [e]- [i] combination the most, 3 of the words they remembered were not actual items on the experiment. However, in those words (*kevi, sevi, vebi*) both the consonants and the vowels were the sounds used in the experiments. These point out that they understood the logic of the experiment, and were aware of the rules. If they did not know the rules, there would also be some words that violated vowel harmony in the words they remembered. However, even if they made up words the fact that those words obeyed vowel harmony showed that they learnt vowel harmony as the one single rule common about these words.

3.3.1.2. Words remembered by subjects trained in Disharmony Condition of Backness Harmony

The total number of words remembered by the subjects trained on backness harmony was 44. 68.18% of the words they remembered were actually on the training phase of the experiment. Out of these 44 words, 3 words violated the condition they are trained on, i.e. disharmony. That is, 93.19% of the words the subjects wrote down were obeying the condition they were trained on. 2 of these 3 words obeyed backness harmony instead (*pegi* and *muzo*), and one words obeyed height harmony (*tubi*). 20 of the 44 words, that is 45.45 %, remembered had [i] and [o] (in either order) combination; and 22 of the words (50%) had [o]- [u] combination (either with [o] following [u] or vice versa). As can be seen from the following table 46, subjects trained in the backness disharmony condition remembered u-e strings more than other vowel strings. This was followed by o-i.

Table 46: The strings and the percentages of words remembered

Vowels in the words remembered	**Percentages**
o-i	27.2%
i-o	18.1%
e-u	9%
u-e	36.3%

Table 47 below shows the distributions with the actual words they remembered in detail:

Table 47: The distributions of words remembered by backness disharmony subjects

	[o]- [i]	[i]- [o]	[e]- [u]	[u]- [e]	Others
Words remembered by Backness Disharmony subjects	***fogi***, *dogi*, ***tovi, kobi, kovi***, ***dobi, fobi, gozi, gobi***, ***tobi***	***fizo***, ***kibo, pigo***, ***bigo, tigo***, ***figo***	*pedu*, ***sezu, dezu***, ***pevu***,	***suve***, ***duve, tube***, ***gube, sude, kuge, dube***, ***pube, suze***, *fuve*, ***guve, kuve, tuve***	*pegi, tubi, muzo*
Number of actual words	9 words	6 words	3 words	12 words	0 words
Total	14 words	6 words	5 words	16 words	3 words

3.3.1.3. Words remembered by subjects trained in mixed Condition of Backness Harmony

Even though subjects were presented with a mixed pattern, where there were both harmony words and disharmony words, the words subjects remembered all have either backness harmony or backness disharmony, as the words they saw. The total number of words remembered by the subjects trained on backness harmony was 56. 83.92% , that is 47, of these words were actual words they saw on the training phase of the experiment. Out of these 56 words, all the words obeyed the condition they were trained on. 30 of the 56 words, that is 53.57 %, remembered had vowel harmony (either with [o] following [u] or [i] and [e] or the opposite orders); and 26 of the words (46.43%) had vowel disharmony ([i] and [o] used together or [e] and [u] used together). As can be observed from the following table 48, subjects remembered e-i strings better than others. This was followed by e-u and i-e.

Table 48: The strings and the percentages of words remembered by backness mixed condition subjects

Vowels in the words remembered	**Percentages**
o-i	6.3%
i-o	12.7%
e-u	17%
u-e	8.5%
i-e	17%
e-i	19.1%
o-u	6.3%
u-o	12.7%

Table 49 below shows the distributions with the actual words they remembered in detail:

Table 49: The distributions of words remembered by backness disharmony subjects

	[o]-[i]	[i]-[o]	[e][u]	[u][e]	[i]-[e]	[e]-[i]	[o][u]	[u]-[o]
Words remembered by Backness harmony mixed subjects	***gozi, vozi, povi***	***pigo, pido, zigo, zivo, pivo,*** *gibo,* ***bido***	***gedu, fezu, vebu, segu, pegu, degu,*** *gegu, ketu,* ***devu, zevu***	***puve,*** *fuve,* ***guze, tube, vuze***	***bize, tive, gide,*** *tide,* ***pive, bize, vide, zibe, pide***	***kedi, pevi,*** *sevi,* ***segi, bezi, zegi, pedi***	***tobu, kodu, gozu***	***guvo, vuzo, puzo, pugo, pudo, vugo***
Number of actual words	3 words	6 words	8 words	4 words	8 words	9 words	3 words	6 words
Total	4 words	7 words	10 words	5 words	11 words	10 words	3 words	6 words

3.3.2. Words remembered by height harmony subjects

The task for the height harmony subjects was identical to that of backness harmony subjects. The only difference was the vowels in the words they saw during their training phase. They saw word pairs such as *bivu gezo*, where the vowels in the words were agreeing (height harmony) or disagreeing (height disharmony) in height property. The logic behind asking subjects to write down the words they remembered was the same. If the subject was trained on height harmony he/she was expected to write words with harmony and vice versa. Mixed condition was again used to see any possible bias towards harmony or disharmony, since the subjects saw words from each set. The words they remembered were analyzed to see from which set they remembered more words.

3.3.2.1. Words remembered by subjects trained in Harmony Condition of Height Harmony

As can be observed from the table 50 below, subjects wrote down a total of 78 words they said they remembered. 88.47% of the words they remembered had height harmony. The percentage of the words they remembered correctly was 67.94%, that is the actual words they saw on the experiment. This percentage clearly showed that subjects learned the phonotactic rules of the artificial language they were presented with. They kept this rule even in words that were not actual words they saw.

As the following table indicates, 41.02% of the words they remembered, had [u]- [i] combination (in either order) and 58.98% had [e]- [o] combination (in either order). Subjects remembered words with e-o strings better than others. This was followed by i-u string.

Table 50: The strings and the percentages of words remembered by height harmony subjects

Vowels in the words remembered	**Percentages**
u-i	12.9%
i-u	24.1%
e-o	27.4%
o-e	20.9%

Table 51: The distributions of words remembered by height harmony subjects

	[u]- [i]	[i]- [u]	[e]- [o]	[o]- [e]	Others
Words remembered by height harmony subjects	*duzi*, ***fuzi subi***, ***guzi, kubi***, ***tubi, guzi***, ***vugi, kuzi***	***Sigu***, ***tigu, pizu***, ***fizu, fibu***, ***sigu, vizu, zigu, bivu***, ***vizu, tibu, zibu, tizu***, ***gizu,*** *vibu,* ***tigu***	***devo, sego, gezo***, ***vebo, sebo, zebo, gedo***, ***fedo, gezo***, ***vebo,*** *vego*, ***zego***, ***tedo, zevo, pezo, bego, febo***, ***sedo***	***kobe***, ***dove, soge***, ***fobe, sobe, goze***, ***gobe, boge, tobe***, ***gode, tobe***, ***gove, foge, vobe, goze***	*zigo, gizo, vogi, sogi, vizo, muzo, fido, dodi, vebu*
Number of actual words	8 words	15 words	17 words	13 words	0 words
Total	12 words	20 words	20 words	17 words	9 words

3.3.2.2. Words remembered by subjects trained in Disharmony Condition of Height Harmony

As can be observed from the table 52 below, subjects trained on height disharmony seemed to learn the condition they are trained on since the words 95.39% of the words they remembered had height disharmony. Only 3 words out of 65 words remembered violated the condition they were trained on.

Only 70.76% of the words they said they remembered were actually on the experiment, the rest were not. So, the words they wrote which were not actual words they saw in the experiment also abided to height disharmony. These numbers clearly illustrated that subjects learned that the words they saw were constructed with a phonotactic constraint and this constraint was vowel height disharmony.

58.46% of the words they remembered had [i]-[o] combination (in either order) and the rest had [u]- [e] combination (in either order). As can be seen from the table below, subjects remembered the words that o-i strings better than other words. This was followed by e-u string.

Table 52: The strings and the percentages of words remembered by height disharmony subjects

Vowels in the words remembered	**Percentages**
i-e	16.3%
e-I	26.5%
o-u	20.4%
u-o	30.6%

Table 53: The distributions of words remembered by height disharmony subjects

	[u]- [e]	[e]- [u]	[i]- [o]	[o]- [i]	Others
Words remembered by Height disharmony subjects	*puve,* ***kuve, guve, kuze, sube, fuge, suze****,* ***pude, puze,***	***pedu, devu, sevu****,* ***pevu, sebu, tebu, pezu****,* ***febu, gevu****,* ***kegu, kedu****,* ***tegu, bezu***	***digo, vido, vibo, givo, pivo****, zigo, dibo,* ***gibo, zido, povi, pivo****,* ***fivo,*** *zino*	***gobi, kobi, povi, dogi, dovi****,* ***povi, sozi, todi, vogi, vodi, godi****,* ***kozi, fogi, zobi, zogi***	kidu, pedo, gebo
Number of actual words	8 words	13 words	10 words	15 words	0 words
Total	9 words	15 words	16 words	22 words	3 words

3.3.2.3. Words Remembered by Subjects Trained in Mixed Condition of Height Harmony

As can be observed from the table 54 below, subjects trained on height mixed condition remembered a total of 55 words. Of these 55 words, 81.81% were actually words they saw on the training phase. 56.36% of the words they remembered had height harmony ([i] and [u] used together and [e] and [o] used together). The fact that more than half of the words the subjects remembered had height harmony showed that they found it a little easier to restore words that had height harmony compared to height disharmony.

There was one subject trained on the mixed condition who wrote down *vago* as one of the words he/ she remembered but [a] was not one of the vowels used in the experiment. As can be observed from the table below, it was the words with o-e string that subjects remembered better. This was followed by e-o.

Table 54: The strings and the percentages of words remembered by height mixed condition subjects

Vowels in the words remembered	**Percentages**
o-i	13%
i-o	10.8%
e-u	8.6%
u-e	4.3%
e-o	15.2%
i-u	13%
o-e	19.5%
u-i	13%

Table 55: The distributions of words remembered by height mixed subjects

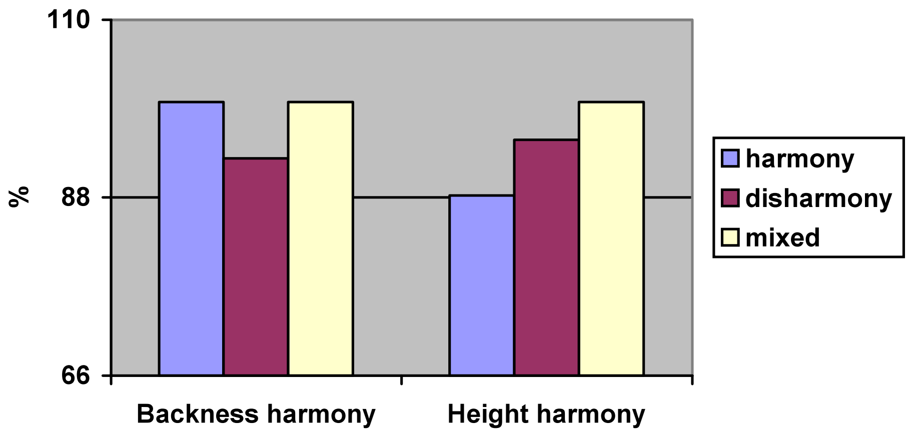
	[o]- [i]	[i]- [o]	[e]-[u]	[u]-[e]	[e]-[o]	[i]-[u]	[o]-[e]	[u]-[i]
Words remembered by Backness harmony mixed subjects	***zodi, bogi,*** *togi,* ***tobi, dovi, dogi, vogi,*** *zosi, dozi*	***zibo, vido,*** *zigo,* ***kido,*** *zipo, zigo,* ***vibo, pivo,***	***febu, devu,*** *segu,* ***pezu, tezu***	***duve, suge***	***Fego, tebo, sego, febo, fevo, tedo, sezo***	*sizu,* ***kizu, kigu, pigu, digu, bigu, pigu***	***dove****,* ***koze, fobe, voge, doge, soge, sove, voge, poge***	***fuvi,*** *zuzi,* ***pubi, kuvi, puzi, zudi, bugi,*** *suzi*
Number of actual words	6 words	5 words	4 words	2 words	7 words	6 words	9 words	6 words
Total	9 words	8 words	5 words	2 words	7 words	7 words	9 words	8 words

3.3.2. General Discussion of Words Remembered

This part of the experiment where the subjects wrote down the words they remembered from the experiment aimed to test whether subjects learned the condition they were trained on. The assumption behind this test was that if the subjects learned that the condition they were trained on had certain phonotactic constraints, they were more likely to adhere to these constraints in the words they wrote down.

The results of the mixed condition subjects for both backness and height harmony would show any bias on the side of the subjects towards harmony or disharmony. Since the words they saw was a combination of both lists, remembering more words from one condition would clerly point to a bias towards that condition.

As can be observed from the following graph 4, the results clearly revealed that subjects in all conditions learnt the condition they were trained on. There were only very few words listed by the subjects that violated the condition they were trained on. As was the case for test phase, the subjects trained in backness harmony condition were more successful at writing words that adhered to the condition they are trained on. All the words they wrote down obeyed the condition they were trained on. This pointed out to the fact that harmony condition of the backness harmony was easier for Turkish subjects.



Graph 4: Comparison of the words remembered by all subjects trained in different conditions

The results of the subjects trained in mixed condition showed a bias towards harmony both for backness harmony and height harmony subjects. Subjects from both backness and height harmony conditions remembered more words having harmony, although the number of words they saw having harmony and disharmony were exactly the same.

3.4. Further studies

This study can be used for both theoretical studies in vowel harmony and in language teaching.

A speaker whose native language has vowel harmony tends to learn a foreign language much more easily if it also has a system of vowel harmony, as suggested by the finding that Turkish speakers found it easier to learn an artificial language with vowel harmony. It would also be interesting to do a similar vowel harmony experiment with subjects who did not speak standard Turkish since there are differences in the application of vowel harmony in different dialects of Turkish. To illustrate words such as *pamuk,* *hamur* and *tavuk* are pronounced as *pamık, hamır* and *tavık*, respectively (Sofu, personal communication). Literacy and education may also have an affect since writing affects pronounciation.

CHAPTER 4
CONCLUSION

This work aimed at analyzing whether vowel harmony is a pattern which would be easy to learn for Turkish speakers that already have harmony in their language. For this purpose subjects were presented with an artificial language having different types of harmony. The analysis of the performance of subjects on this artificial language had three parts: speech errors, test phase and analysis of the words remembered.

As a result of our analysis of the speech errors some general conclusions can be drawn. There were clear patterns. The speech errors subjects made reflected that they were learning the condition they were trained on. Subjects followed the pattern they were trained on. The harmony subjects adhered to harmony even though they made speech errors. Disharmony subjects still made disharmonic speech errors. Mixed group subjects made errors where they created harmony and errors where they created disharmony as expected, since they were trained on both sets. Thus, subjects learned the system they were trained on as long as there was a coherent pattern. Moreover, disharmonic pattern was even easier than no pattern.

It seems that the phonological properties of the subjects' native language had an effect on the speech errors. The subjects trained in the harmony condition of backness harmony made fewer errors compared to other conditions, since the phonology of the backness harmony system in the artificial language was closer to their native language, Turkish. Although, the properties of vowel harmony in Turkish were not exactly the same as the properties of the harmony system in the artificial language, it was similar. The fact that subjects made fewer speech errors with vowels in backness harmony condition (VBH) compared to the height harmony condition (VHH) also stressed the effect of native language on learning an artifical system. Backness harmony used in the experiment was closer to the vowel harmony attested in Turkish compared with the properties of height harmony used in the experiment.

The fact that backness harmony was easier for Turkish subjects compared to height harmony may also be linked to the properties of the vowels used in the experimental items. The back harmonic forms were also harmonic with respect to rounding by definition, since the back vowels used in the experiment were also rounded. It is possible that the ability to recycle two features, backness and rounding, offered a benefit for speakers which recycling only one feature, height, did not. This is parallel to the findings of Linebaugh (2007), where English and Spanish subjects were reported to have more difficulty with height harmony when compared to backness harmony. However, the fact that the same effect was found for Korean speakers (Oh & Cole, 2006) only on backness harmony items but not on height harmony items (in an experiment where height harmony items also shared rounding properties) suggested that it cannot be attributed to the sharing of two feature values as opposed to sharing one feature value. These results lead out to the conclusion that there is a facilitative affect for back harmonic sequences, which is not dependent on the number of features shared. It appears that back harmony provides a benefit that is not found for height harmony.

The divergent findings which were also attested in our study with respect to the two different types of vowel harmony are more understandable when looking at potential benefits related to economy in the movement of articulators. It is also possible that the lack of a facilitative effect for height harmony is attributable to the fact that, as Ladefoged (1990) pointed out, the feature [high] does not have a clear articulatory correlate. The physiological correlate for the feature [high] is dependent upon other features. For instance, the physical manifestation of [+high] is different for back high vowels than for front high vowels. Different tongue muscles are used in producing the raised tongue body for [i] and [u]. Ladefoged (1990) found that speakers adopt a variety of strategies in implementing the [high] feature. It should be clear that this is not to deny the existence of [high] as a feature. But, phonological vowel height features define classes of vowels that participate in rules, but height features are more likely to have been derived from perceptual rather than articulatory categorization (Ladefoged, 1990; Boersma, 1998). If the influence of vowel harmony in facilitating speech production derives from ease of articulation, facilitation would be expected when features have clear articulatory correlates, and especially when the same muscles are involved in realizing a feature value. Compared to the [high] feature, the articulatory correlates for the [back] feature are much more isolable and, therefore, back harmonic sequences may facilitate speech production in a way that height harmonic sequences do not (Linebaugh, 2007).

The results of this study also indicate that back vowel harmony facilitates speech production. Fewer errors were made when words contain back harmonic vowel combinations. Vowel height harmony did not offer the same benefit. This study was conducted using Turkish speakers. But similar results have been found for English speakers (Cole, Dell, & Khasanova, 2002), Spanish speakers (Linebaugh, 2007) and Korean speakers (Oh & Cole, 2006) pointing out to the finding that vowel backness harmony is easier for speakers than height harmony.

However, there is no prediction that vowel backness harmony will be found to exhibit greater stability than vowel height harmony. Once a sound pattern becomes part of phonological grammar, there is no expectation that the pattern will remain linked to the phonetic factors that led to the pattern. Once established phonologically, vowel backness harmony is just as likely as vowel height harmony to deteriorate or be lost (Linebaugh, 2007). As a result of the great number of borrowed words in Turkish lexicon, there are many violations of vowel harmony. An analysis of the borrowed words in Turkish lexicon would clearly help to see whether they are modified in direction of vowel backness or height harmony.

The results of the experiment also indicate that backness harmony facilitates speech production, and thus, that ease of articulation could play an important role in the derivation of VBH. Contrarily, height harmony offers no similar benefit to speech production, and there is no reason to believe that ease of articulation is a major factor in the development of VHH. If vowel harmony is the result of the grammaticalization of variation that arises due to the natural tendency to reduce effort and/or the failure to compensate for VCV coarticulation effects in speech, then there is an expectation that the phonetic asymmetries will be reflected in asymmetries between phonological VBH systems and phonological VHH systems. That is precisely what the survey results show.

Given the robust phonetic effects of ease of articulation with respect to back harmony, it is possible to state that it is not a coincidence that the most robust types of vowel harmony are the backness harmony systems found in UA languages such as Hungarian and Turkish. As has been discussed in the literature review section, VBH in these languages is pervasive and robust. Vowel height harmony systems, on the other hand, are less robust. There are often contextual constraints, such as stress dependency, and generally only a subset of the vowels participates in harmony. In addition, height harmony is a dominant type of harmony, where a particular feature value predominates and spreads. Any particular vowel is either a trigger or a target of harmony, not both. Contrastively, in VBH, vowels are both triggers and targets of harmony. There is ample evidence that vowel backness harmony is more robust and more systematic than vowel height harmony. The typological robustness of vowel backness harmony systems compared to vowel height harmony systems, is consistent with the findings that backness harmony facilitates speech production in a way that height harmony does not.

The consistency between the experimental findings and the typological characteristics of the two types of tongue body harmony suggests that ease of articulation and V-V coarticulation may indeed be phonetic precursors to vowel harmony. As Linebaugh (2007) pointed out, there are asymmetric findings with respect to the influence of these two phonetic factors, and that asymmetry is matched in the typological findings of phonological vowel harmony. The phonetic phenomena that are likely to be the underpinnings of the two types of harmony are different, so the expectation is that the two types of harmony, as grammaticizations of those phonetic phenomena, will be different. There is no unified phenomenon of vowel harmony because the origins of the two types of harmony are different. Thus the view that the reinterpretation of unintended phonetic effects leads to sound change is supported.

It has been suggested that ease of articulation is a factor that leads to the development of vowel harmony (Jesperson, 1942; Blevins, 2004). The results of the present experiment, however, indicate that different types of VH are not equivalent when it comes to benefits related to speech production. There is clear asymmetry in both the speech error and test data. Based on the experimental finding reported above, we may expect that ease of articulation can play a role in the establishment of vowel backness harmony, but it is not similarly expected that ease of articulation would result in the establishment of vowel height harmony. Forms that contain back harmonic sequences are easier to produce. Forms that contain height harmonic sequences are not significantly easier to produce. However, height harmony was found to be easier than the lack of any system, as was suggested by the results of mixed harmony subjects.

The speech errors of subjects indicated that the constraints on articulation consist of two principles. First, for speech errors where one vowel is substituted for another, substitutions that differ from the target vowel by one feature are more likely than substitutions that differ from the target by two features. The subjects were more likely to keep the properties of the condition they were trained on even in their speech errors: the harmony subjects did not violate harmony in their speech errors. This was parallel to the findings of Walker (2007) who suggested that the consonants that participated in speech errors are interpreted as more similar than those that participated less. It seems that similarity has a big influence on speech sounds' potential to interact in certain phonological processes. Sounds that are minimally different present difficulties in speech planning, they lead to misordering and substitution errors. This tendency was named as the phonetic-similarity constraint in Levelt (1989). This conditions states that in speech errors it is often the case that one phoneme intrudes upon and replaces another phoneme, and there is a tendency for the intruding phoneme to be similar to the target with respect to distinctive features. This was the case with the errors in this artificial language experiment as well.

Harmony subjects also did not insert a vowel other than the four vowels used in the experiment in their speech errors. This supports previous studies done on artificial language learning by Dell et al.(2000). In their study they also found that speech errors obey language-wide phonotactic constraints, so all the errors lead to possible sound sequences in the language. Another point they underlined is that there is an effect of recent experience, that is recently experienced sound forms are more accessible. This is also valid for the current study since subjects obeyed the vowel harmony rules of the artificial language rather than the actual rules of vowel harmony in their native language. Dell et al.(2000) came to the conclusion that the learning mechanism has three properties: it is sensitive to recent experience, it is implicit and it is capable of generalization. That is, even though people make speech errors the errors still conform to the phonology of the language. All these three properties were true for the artificial language system used in the present study.

Subjects trained in the harmony condition of both backness and height harmony mostly did switching errors, not modifying the properties of the condition they were trained on but just modifying the order of the vowels. It was the case that the first vowel was more prone to errors compared to the second vowel. This finding was again parallel to previous studies. As was summarized in the literature review section, Shattuck-Hufnagel (1986) also found that word-initial vowel errors were more common than non-initial errors. The fact that disharmony subjects did not modify the vowels so that the result was vowel identity also revealed that they were already aware of the fact that the original vowels were phonetically different from each other.

Speech errors with vowels indicate that changing the height of a vowel was more likely than changing its backness. This could reflect the fact that in our experiment we only used a subset of the possible range of heights (high and mid), whereas we used the full range of backness (front and back). It could also reflect more general principle. Possible pieces of evidence include the relative prevalence of height versus backness harmony in the world's languages, as well as typological facts about the shapes of vowel inventories. These principles account for several patterns in the data, as follows. Vowel errors that can be explained in terms of changing one feature were much more common than errors that involve multiple features and errors than can be explained in terms of changing height were much more common than errors of backness.

Moreover, consonant errors also revealed the fact that subjects learned the properties of the artificial language presented to them. None of the subjects in all six conditions of the experiment inserted a consonant other than the consonants in the phonetic inventory of the artificial language. The most common error with consonants was to modify the voicing feature; this type of error is indeed parallel to natural language speech errors

(Sofu, 2001; Shattuck- Hufnagel, 1986). The fact that vowels were only replaced by vowels and consonants only with consonants also indicated the fact that speech errors in the artificial language resemble those in natural language production (Sofu, 2001).

Another pattern that was revealed by the speech errors of both backness harmony and height harmony subjects was that consonants were more prone to speech errors than vowels. The fact that mixed condition subjects in both height and backness harmony made more speech errors with vowels indicated that a lack of a pattern was confusing for subjects. When the subjects in the harmony conditions of both backness and height harmony were compared, it was revealed that backness harmony subjects made much lesser errors violating harmony. Since all subjects were speaking Turkish as their native language, backness harmony was closer to the vowel harmony patterns in their native language, which may facilitate learning backness harmony in the experiment.

The second part of the experiment was the test phase, where the subjects were asked to choose the word that resembles the words in their training phase. The results of the test phase of the backness harmony experiment revealed that Turkish subjects indeed found it easier when the artificial language they were presented with had a harmony system that was similar to their native language. The results of the backness harmony experiment clearly revealed this finding in that the harmony subjects chose a word with harmony in the test phase. The results also showed that Turkish subjects learned backness disharmony but found it difficult to learn the mixed system where there was no sound pattern. When Turkish subjects were trained on a different type of harmony than that in their native language (height harmony) the results of the test phase clearly indicated that it was more difficult for them to learn that different kind of harmony.

The third part of the experiment was where the subjects wrote down the words they remembered from the experiment. The analysis of the words remembered also clearly revealed that subjects in all conditions learnt the condition they are trained on. There were only very few words listed by the subjects that violated the condition they were trained on. As was the case for test phase, again backness harmony subjects were more successful at writing words that adhered to the condition they are trained on, clearly demonstating the effect of phonological properties of the native language.

In the experiment we showed that Turkish speakers learn the phonological properties of the language they were trained on whether it is a language of vowel harmony or disharmony. It is a crucial finding that they learned both systems since Turkish is a language that has vowel harmony. Although, backness harmony system was easier to learn for Turkish subjects the fact that they also learned disharmony showed that as long as there is a phonotactic system to the artificial language it can be learned. The learning effect is greatly reduced if the subjects see a mixed system that employs both harmony and disharmony. This phenomenon was due to the fact that subjects expect a coherent phonotactic pattern to learn a language.

In a more general framework, this experiment supports both Walker (2005) and Kaun (2004) in that vowel harmony was found to facilitate both production and perception, respectively. The finding that subjects trained on vowel harmony (whether backness or height) made fewer speech errors support the claim that vowel harmony facilitates language production. The other finding that harmony subjects performed better on the test phase and the words remembered illustrates that vowel harmony was a phenomenon that helped Turkish speakers in learning and remembering the artificial language system.

These results are in line with the phonological properties of languages. Speakers use the phonotactics properties of the language system they are exposed to. They do not tend to violate the basic properties of the system. It thus appears that the task is sensitive to the properties speakers use in speech. The learning task is therefore a promising tool for further research since it allows good control over the phonological properties of the artificial language and the amount of exposure listeners receive. However, this dissertation has considered only tongue body harmony. It would be fruitful to explore how ATR harmony fits into the picture. Is it more like vowel backness harmony or vowel height harmony? Or is it yet another type of harmony? An extensive exploration of the finer details of ATR harmony across many languages has the potential to add to our understanding of harmony processes.

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Appendix 1: List of words used in Harmony condition of Backness Harmony

bovu	gubo	vige	tedi
sebi	zogu	fuzo	vize
bive	sedi	todu	bugo
pobu	tugo	fide	fegi
gezi	kovu	puzo	dive
gobu	fugo	vige	debi
buvo	bige	sezi	gozu
five	pedi	tovu	sugo
guvo	dize	tegi	vozu
gedi	godu	vubo	gize
zibe	bezi	bogu	vugo
pide	zedi	dovu	duzo
vogu	duvo	tibe	tevi
dugo	zive	pebi	fozu
puvo	pize	kezi	zovu
zige	sezi	fovu	kuvo
tovu	fuzo	gibe	fedi
gubo	zive	pezi	dobu
sibe	fezi	gobu	fubo
kegi	tozu	budo	gide
tezi	dozu	tubo	sige
tevi	vozu	bugo	fize
fevi	pozu	kuvo	vize
zuvo	pige	vegi	sogu
zide	bedi	vogu	guvo
fuvo	fige	fedi	sozu
bogu	tubo	pive	kezi
bevi	sozu	sugo	dige
povu	tuzo	kige	kegi
duzo	tize	vedi	togu
todu	puzo	tibe	tegi

zudo	dibe	fezi	fogu
vide	dezi	govu	fuvo
dezi	pogu	vuzo	dige
zodu	kubo	pive	kedi
segi	gozu	pugo	tige
suvo	sive	zebi	tozu
kodu	zudo	tive	gedi
zevi	dobu	fudo	give
tugo	pize	bezi	dozu
pide	febi	vobu	budo
kebi	fozu	sudo	tige
vudo	fige	pedi	zogu
fovu	pugo	kive	vezi
dubo	kize	gebi	godu
kobu	subo	vibe	vedi
pegi	fogu	fugo	gize
bedi	kozu	subo	fize
kedi	zovu	vugo	dive
tobu	vuzo	fide	vegi
duvo	tize	degi	kozu
vobu	kudo	kige	zebi
bive	gezi	zodu	puvo
tedi	sodu	fubo	give
zide	degi	kobu	zubo
kide	pezi	sovu	sudo
vide	zegi	tobu	pubo
bozu	kuzo	tive	gebi
tebi	togu	zubo	bide
zugo	pige	zegi	pogu
dogu	vudo	kive	fevi
sibe	pegi	kodu	dubo
zedi	fodu	kudo	bide

zige	segi	podu	dugo
side	pevi	bozu	vubo
sovu	fudo	bize	pebi
guzo	dibe	debi	sodu
podu	buvo	bize	kebi
five	sebi	dogu	pudo
tudo	sive	febi	fodu
kubo	dize	sedi	kovu
pudo	bige	vezi	pozu
devi	zobu	kuzo	gide
zibe	tezi	pobu	zuvo
fegi	sogu	pubo	sige
kide	zevi	bovu	guzo
govu	zugo	gibe	bevi
tuzo	kize	pevi	zobu
dovu	tudo	vibe	tebi
side	devi	povu	suvo

Appendix 2: List of words used in Disharmony condition of Backness Harmony

tido	sodi	gezu	pude
vezu	fuze	vizo	kogi
segu	fude	zivo	godi
pido	podi	fegu	gube
zodi	zegu	guze	vido
kigo	zodi	fezu	sude
gozi	pebu	buve	fizo
guve	dizo	vozi	tebu
dezu	tuve	bido	fogi
tido	bodi	dezu	guve
pogi	degu	gude	zibo
bovi	tegu	buge	sizo
suze	bivo	vodi	bedu
vuze	pivo	vogi	gebu
sude	givo	tobi	pegu
zube	kivo	kovi	kezu
gido	zobi	devu	suge
vube	tivo	kogi	gedu
pibo	bogi	tedu	vube
godi	bedu	pude	sibo
devu	vude	pizo	tobi
kodi	sevu	kuze	zibo
bogi	sedu	fuge	tigo
kude	tivo	zogi	begu
vibo	govi	sezu	buge
dozi	kebu	duge	zigo
fovi	begu	fuze	sizo
tuve	bivo	sodi	tezu
pozi	febu	suve	dibo
kube	zido	vobi	sedu
sebu	vuge	bigo	todi

fegu	duve	pigo	povi
sido	pobi	zebu	kuge
povi	bezu	tude	tibo
podi	pevu	bude	tibo
puze	fivo	fobi	kebu
zebu	buve	bido	vozi
sezu	gude	fido	tovi
gido	kozi	segu	suze
gezu	tube	zivo	vodi
sobi	vebu	zuve	fizo
divo	zovi	bevu	fube
fedu	guze	kido	dobi
vedu	duze	bigo	sobi
fodi	kezu	vuge	zigo
duze	dizo	pobi	pebu
kobi	gedu	dube	tigo
gube	zido	fozi	bezu
kuve	gizo	bozi	zegu
sube	kivo	todi	vebu
fevu	pube	digo	kodi
figo	fodi	zevu	puze
sigo	zogi	vezu	dube
sigo	fovi	gevu	buze
kozi	zedu	vude	sibo
pibo	vobi	tevu	tude
fogi	tebu	kuge	kibo
kigo	bozi	fedu	suve
zovi	gebu	puve	dibo
pido	gobi	pezu	duge
sido	gozi	vedu	sube
figo	kovi	sebu	zuve
buze	fibo	tovi	tegu

zude	pivo	sogi	sevu
tedu	kube	vizo	kobi
divo	vogi	kedu	kuze
fube	gizo	dobi	febu
kedu	puve	digo	sogi
fude	givo	zobi	zedu
gevu	kude	fido	bovi
vibo	pogi	fevu	zude
pezu	bude	tizo	fobi
bevu	vuze	kido	pozi
pube	fibo	govi	degu
duve	fivo	gobi	pevu
dovi	pegu	suge	vido
zevu	zube	tizo	dozi
tevu	fuge	pigo	fozi
fezu	kuve	pizo	dovi
bodi	tezu	tube	kibo

Appendix 3: List of words used in Mixed condition of Backness Harmony

fuzo	side	sezi	sozu
zobu	zuvo	five	kedi
dozi	vedu	tuve	sizo
bive	fevi	dogu	tuzo
bide	febi	zovu	zubo
fibo	godi	fevu	suze
zedu	zuve	kivo	zogi
kovu	pugo	pide	fedi
fubo	zide	bevi	tobu
pezu	tube	pibo	kodi
fovi	gezu	guze	digo
dobu	fudo	zive	devi
gude	tigo	tobi	febu
fido	vozi	vezu	fuge
budo	vibe	gezi	dovu
puvo	zige	zedi	pobu
zegi	podu	duzo	fige
gide	tevi	todu	fuvo
bige	segi	dozu	gubo
sezu	bude	tido	fobi
fugo	tive	degi	fodu
kude	dibo	vodi	kebu
fezu	puze	kibo	vobi
bezu	gube	fizo	fogi
pegi	godu	tugo	pige
vuge	tivo	pogi	devu
zube	vido	kozi	zegu
dezu	buve	zigo	kogi
gebi	sogu	vudo	pive
duve	gizo	kobi	pebu
tedi	kobu	vubo	gibe

pizo	sodi	fedu	vude
fube	bido	zobi	pegu
tevu	dube	bivo	kovi
kige	fegi	bozu	kudo
kigo	sogi	gebu	buge
gobu	duvo	fize	pevi
kive	tegi	kodu	buvo
sodu	vuzo	dibe	kegi
tize	pedi	vobu	guvo
vibo	gobi	kedu	pube
vige	kezi	pogu	dubo
zugo	fide	gedi	tovu
suve	sigo	gozi	pevu
bedi	vogu	dugo	dive
zivo	povi	gevu	duge
fezi	zodu	puzo	tibe
fivo	govi	sevu	sube
zebi	vozu	guzo	bize
suge	tibo	pobi	zevu
povu	tubo	vide	sebi
bedu	duze	dizo	bovi
fovu	kuzo	kize	bezi
dobi	zebu	sude	vizo
kuvo	give	tebi	bovu
subo	sive	debi	pozu
fegu	fude	tizo	fodi
zovi	degu	tude	zido
tovi	sebu	fuze	pido
sobi	tegu	puve	divo
dovi	vebu	kube	kido
zibo	pozi	sedu	zude
bigo	bozi	tebu	kuze

sudo	dize	vezi	gozu
zudo	zibe	vedi	sovu
kozu	kubo	sige	dezi
zevi	togu	pubo	kide
sibo	bogi	begu	kuge
vize	sedi	zogu	bugo
todi	segu	kuve	sido
vogi	kezu	buze	pigo
govu	suvo	gize	pezi
fozu	vugo	sibe	tezi
pebi	tozu	pudo	dige
fozi	tezu	vube	figo
vegi	fogu	sugo	tige
pize	kebi	bogu	tudo
guve	givo	podi	tedu
gedu	pude	gido	zodi
vuze	pivo	bodi	bevu

Appendix 4: List of words used in Harmony condition of Height Harmony

bivu	kezo	vobe	fuzi
sezo	goze	kuvi	gidu
kidu	zebo	tobe	kuzi
pugi	pizu	kezo	kobe
dibu	dezo	soge	kubi
dubi	bigu	vebo	foze
sibu	sezo	gobe	vugi
vugi	zivu	tevo	voze
debo	pobe	gubi	pibu
bove	zuvi	figu	pebo
bezo	foze	guzi	kibu
vezo	poge	zubi	fizu
kigu	debo	gove	vudi
bevo	toge	zuvi	fizu
pedo	kobe	zudi	sigu
gove	sudi	dizu	kego
poze	sugi	kizu	kebo
gibu	kedo	zove	puzi
bego	dobe	vuzi	pivu
kego	zoge	budi	pibu
zobe	gubi	zigu	tebo
sivu	dego	zode	fuvi
gudi	tidu	sebo	sobe
dibu	devo	pode	budi
suzi	fibu	sego	sode
fivu	tedo	bove	fugi
vedo	gode	pubi	pigu
pidu	sedo	pove	kudi
fivu	bevo	doge	guvi
sivu	fevo	fove	suzi
guvi	fidu	gezo	poge

koze	pudi	gizu	zego
dugi	tivu	tebo	dobe
kubi	digu	bedo	fobe
tego	tove	kugi	bizu
pove	duvi	vidu	sego
tugi	fibu	sedo	soze
kove	pugi	figu	fego
pego	soze	duvi	pivu
fevo	toze	subi	divu
kebo	sobe	puzi	pigu
soge	fudi	tizu	kevo
doge	puvi	tibu	vezo
vubi	tidu	kedo	bode
bivu	pedo	kove	bugi
tezo	bode	tuvi	kibu
sudi	tivu	gebo	pobe
boge	vubi	sidu	bezo
kode	kuvi	sidu	vebo
fode	tugi	zigu	bego
pode	tubi	dizu	pezo
gobe	suvi	zibu	zevo
fego	sove	fugi	sigu
zevo	voze	fuvi	gidu
zode	subi	zibu	tevo
gibu	tezo	boge	dubi
bugi	tigu	pebo	sove
puvi	tigu	tedo	toge
givu	vedo	poze	gudi
fudi	zidu	devo	dove
pidu	pego	fode	dugi
zove	tuvi	kizu	sebo
suvi	bigu	febo	goze

fubi	pizu	gevo	voge
foge	pubi	tibu	gezo
tobe	kugi	tizu	bedo
buvi	zivu	dego	toze
pudi	digu	zebo	tove
dezo	dove	tubi	vizu
fove	buvi	vidu	fedo
kigu	gebo	zobe	vuzi
vudi	zidu	pezo	zoge
fedo	sode	kudi	divu
kidu	tego	koze	fubi
zego	voge	fuzi	bizu
sibu	febo	kode	guzi
kevo	fobe	kuzi	vizu
givu	gedo	foge	zubi
sugi	fidu	gedo	gode
vobe	zudi	gizu	gevo

Appendix 5: List of words used in Disharmony condition of Height Harmony

gezu	fuge	tigo	dovi
fuge	tivo	sovi	kedu
tebu	pude	bido	vobi
vozi	sebu	fuze	dizo
godi	fezu	buve	zivo
vido	godi	tedu	puze
vizo	bodi	gezu	fude
fizo	tovi	zevu	tube
tozi	gebu	suze	sigo
vuge	fivo	fozi	sebu
pebu	guze	kizo	kobi
sibo	tozi	tebu	zuve
tizo	pobi	vezu	sube
kebu	suze	tibo	dobi
divo	sobi	tevu	tuze
kozi	zegu	sube	pido
tuze	vigo	zogi	zebu
zube	figo	bozi	vegu
guze	pigo	pobi	febu
kezu	tude	sivo	fovi
puge	figo	sodi	fegu
tedu	sude	gido	pozi
fude	vibo	kovi	kegu
bevu	zuge	tigo	kovi
tude	fibo	podi	pegu
zuve	digo	gobi	debu
duge	fivo	vodi	gevu
pozi	sevu	bude	zivo
fuve	sizo	kodi	sezu
sobi	fegu	duve	kibo
vogi	sezu	kude	givo

todi	pegu	buze	kivo
govi	gedu	gude	zido
bizo	dogi	tezu	fuve
tido	podi	vedu	bude
fizo	vodi	pedu	fuze
vobi	debu	suge	sigo
begu	vube	gibo	zogi
sude	sizo	bogi	fezu
bezu	zude	zibo	vozi
tizo	fobi	pebu	zube
pezu	guve	tibo	govi
fube	tivo	zodi	devu
bovi	zebu	duze	kibo
pivo	zovi	bezu	vuge
pude	bivo	pogi	gebu
zude	digo	povi	bedu
sedu	kuve	bido	gobi
bizo	tobi	begu	duze
kigo	sozi	pezu	kuge
tezu	suve	bigo	vogi
vezu	vuze	pibo	kogi
vedu	buze	gido	zobi
pedu	vude	zibo	fozi
puze	fibo	zobi	sevu
sozi	vebu	zuge	zido
tido	todi	kezu	fube
vizo	sovi	fedu	buge
tube	pigo	kogi	zegu
vido	bogi	tegu	kude
dovi	kegu	kuze	kido
fobi	febu	vuze	sido
bodi	kedu	pube	kido

kigo	fogi	bevu	kuze
divo	sodi	dezu	tuge
guve	vibo	fogi	vebu
tovi	gevu	vude	pido
tevu	puge	gibo	bovi
sibo	pogi	kebu	gude
suve	vigo	tobi	pevu
fovi	devu	buge	kivo
tegu	buve	bigo	kodi
dezu	duve	kizo	bozi
kuge	bivo	dobi	gedu
kobi	vegu	tuge	sido
zovi	bedu	kuve	dizo
zevu	duge	pibo	kozi
fedu	pube	sivo	zodi
pivo	povi	sedu	suge
dogi	pevu	vube	givo

Appendix 6: List of words used in Mixed condition of Height Harmony

pizu	fego	poze	zuvi
sibo	zovi	bevu	sude
duve	tibo	fovi	pebu
dego	gove	puvi	fivu
bigu	sedo	sobe	guvi
gubi	figu	kebo	dove
sodi	kebu	vude	sivo
povi	febu	vube	figo
subi	gizu	vezo	doge
vizo	pobi	vezu	tuze
kovi	gezu	puge	sido
duvi	dizu	tevo	fobe
poge	vuzi	dibu	pego
dezo	dobe	fugi	vidu
pode	vugi	kidu	kevo
zube	kigo	bovi	tegu
pibu	pebo	foge	fubi
fidu	sego	toze	dubi
vuge	vibo	kodi	kedu
kuve	digo	vozi	zebu
zigu	zebo	bove	bugi
bozi	gebu	kuge	tido
sugi	sidu	kezo	gobe
zuge	zivo	kogi	sevu
vobe	fuvi	bivu	vedo
fibo	tozi	debu	gude
kibu	vebo	koze	suzi
fezu	kude	pivo	fobi
fude	tigo	vodi	tedu
tivo	sozi	dezu	fuve
devo	gode	dugi	tizu

tuvi	fibu	zego	tobe
kugi	zibu	sezo	kove
pobe	guzi	zivu	tebo
gobi	fegu	bude	fivo
bido	godi	gevu	sube
fuze	tizo	pogi	vebu
buvi	tivu	febo	boge
zevu	tube	bivo	dovi
pezo	zobe	vudi	sigu
dizo	vobi	fedu	tuge
tidu	tedo	zove	fuzi
zegu	suge	bigo	zodi
suve	vido	tovi	sebu
gibo	kozi	tezu	puze
pevu	buge	kido	bogi
bego	soze	kuvi	tigu
kizo	dobi	vedu	buve
pugi	tibu	kego	voge
gudi	kigu	bevo	toge
soge	puzi	kizu	gedo
tezo	foze	kudi	pivu
bodi	pezu	pude	vigo
zode	vubi	fizu	zevo
bode	tugi	bizu	bedo
tobi	bezu	buze	kivo
pozi	kegu	zuve	sigo
tevu	pube	pigo	vogi
pedu	guze	fizo	todi
devu	suze	bizo	zobi
voze	zubi	pidu	tego
fudi	sibu	fedo	kobe
podi	pegu	kuze	sizo

tude	kibo	sobi	bedu
divu	pedo	goze	zudi
kezu	duze	pibo	fozi
govi	sedu	zude	gido
gevo	sove	kubi	givu
zido	kobi	begu	guve
tove	pubi	digu	kedo
duge	pido	zogi	gedu
zibo	sovi	tebu	fuge
gebo	fode	budi	gibu
gidu	bezo	zoge	tubi
sebo	sode	sudi	pigu
sivu	debo	fove	pudi
vegu	fube	givo	fogi
gezo	pove	kuzi	zidu
sezu	vuze	divo	dogi
kode	suvi	vizu	fevo

Appendix 7: List of test items for backness harmony subjects

buzo	debu
vigo	suzo
fibe	tuze
tozi	gudo
kegu	bodu
pedu	sevi
vodu	sivo
begi	vegu
gibo	size
sobu	zuge
fuve	tuvo
togi	kogu
kevi	kevu
pibe	bizo
sovi	kugo
kibe	kizo
dogi	fobu
sozi	vebi
gevi	tuge
tide	puge

Appendix 8: List of test items for height harmony subjects

vigu	dibo
dube	boze
tuzi	fevu
puve	zedo
buzi	togi
vode	tuve
segu	vego
gozi	doze
gizo	zugi
zedu	sizu
tudi	gube
kivu	zigo
kube	duzi
pevo	dozi
sogi	sevo
fezo	fido
tode	pizo
bidu	kevu
degu	koge
fodi	vibu

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