The Phonetics and Phonology of English Schwa*

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Ahn, Soo-Woong. 2001. **The Phonetics and Phonology of English Schwa.** *Korean Journal of English Language and Linguistics* 1-2, 311-329. This paper wanted to test the reality of English schwa by phonetic and phonological methods. Phonetically it wanted to see acoustic evidence of the relationship between the full vowels and their reduced vowels in the unstressed positions. Phonologically it wanted to prove how systematic the schwa sound is by the constraint-based grammar. As a result, the schwa phenomenon in English was supported both phonetically and phonologically. In the phonetic analysis no relationship was found in the distribution of the F1 and F2 of the full vowels and their reduced vowels in the unstressed syllables of the derived words. The reduced vowels tended to converge into a target of F1 516 and F2 1815. The view that the schwa sounds have a target was supported. On the phonological side the constraint-based tableau produced the successful output by using FAITH(V), *əV, FAITH V[-BACK+HiC], *V[-Low, -TNS]#, REDUCE V[-STR, -TNS] as constraints. No ranking was found. Any violation of the constraints ousted the candidates.

1. Introduction

English schwa has special characteristics. It is a vowel that occurs more often than any other vowel in English, but it is not qualified to be an English phoneme (Giegerich 1992:69).[1)] It is a vowel reduced when an original full vowel loses its stress.[2)] Its

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*I thank professor Bruce Hayes at UCLA linguistics department for giving me the original idea and invaluable advice about this experiment.

[1]This paper agrees to this view.

[2]The contrast between the terms "full vowels" and a "reduced vowel" was used in Wallace's dissertation (1994:1).

tongue position is neutral and relaxed. Hamans (1994:53) says that schwa is an "unarticulated" sound in the sense that there is no particular articulatory movement in the vocal tract. There are several terms used for this sound by studies. This same vowel in a word may be referred to as a 'schwa', an 'unstressed vowel', a 'centralized vowel', a 'reduced vowel', or a 'neutral vowel'.

It is of particular interest whether the schwa can be approached both phonologically and phonetically. It was an abstract phonological entity for many years (Chomsky and Halle 1968; Roach 1991). There are fewer studies for verifying this sound phonetically (Lindblom 1963; Wallace 1994). This study attempts to clarify the reality of this sound phonetically and phonologically. For the phonetic verification this study measures the F1 and F2 of the vowels and plot them on the formant chart using the plotformant developed by Ladefoged at UCLA. The degree of the schwa variation will be looked at to see whether there is any relationship between the full vowels and their reduced vowels in the unstressed positions and whether they tend to converge into a target. Wallace (1994) agrees to the point that there is "a single target" in schwas.[3] For the phonological study, the optimality theory will be used to test the reality of the schwa.

This study will be focused on the following research questions:

(1) What are the acoustic properties of schwa?[4]
- How centralized are the formants of schwa?
- Whether there is any relationship in articulatory positions between the full vowels and their reduced

[3]Schwa "is articulated with a rapid, variable jaw-opening gesture but a fairly precise tongue gesture. There appears to be a single target vowel with a neutral jaw position and a fronted tongue position." (Wallace 1994)

[4]This experiment is a repetition of Ahn's study (2000) with another speaker.

vowels in unstressed positions by measuring the F1 and F2 of each original vowel and its reduced form.

(2) Can the reality of schwa bear out phonologically?

2. The Theoretical Background of Schwa

Schwa is defined as a central vowel with the neutral lip position, having a tongue-raising between half-open and half-close. It occurs only in unstressed syllables as in such words as *balloon, China, random, focus, item, father, Babylon, edible* (Giegerich 1992:73; Kreidler 1989:80). The /ɜ/ sound that occurs in the stressed syllable in such words as *birds, hermit, infer* is not schwa.

2.1. Historical Development of the Schwa Sound

The schwa sound in English is the result of gradual development in the history of the English language over a thousand years. In OE the vowels of the unstressed syllables were much more distinctly pronounced, and were different sounds in accord with the different spellings (Kenyon 1966:202). But even in OE there is some evidence of unstressed vowels being reduced to schwa. This tendency was evidenced in the spelling *e* in East West Saxon in such words as *heofenas* ← *heofon* 'heaven', *fugelas* ← *fugolas* 'bird', *weredum* ← *weorod*, *adesa* ← *adosa* 'adze', etc. (Hogg 1992:247).

Gimson (1972) says that the evidence that such reductions were taking place in unaccented syllables even in OE can be seen in the confusion in the use of vowel letters. OE letters *æ*, *e*, *i* in unaccented syllables were very often confused in the unaccented positions. The back vowels *o* and *u* were also often interchanged. By the eleventh century all these major distinctions of weak [ɛ], [ʊ], and [ɑ] tended to be confused in unaccented

final syllables and were obscured in the direction of [ə]. This tendency continued in the ME period, so that it has been suggested that by the middle of the fifteenth century the vowels of unaccented syllables showed much the same kind of obscuration toward [ə] or [ɪ] as in present day English. Fifteenth century spellings such as *disabey, Bishap, tenne a clocke, sapose* seem to indicate a vowel of the [ə] type (Gimson 1972:125).

These diachronic aspects of the schwa sound could be tested synchronically. This is why this study was necessary.

2.2. Three Positions on English Schwa

The origin of schwa has been the concern of both phoneticians and phonologists. There are several schools of thought. First, there is the view that schwa arises from the application of a productive rule that replaces an underlying full vowel with a neutral, central vowel when the stress level is low enough (Wallace 1994:5). Most variation is then attributed to phonetic environment. This view is against the view that "all the vowels of unstressed syllables are merely positional variants of stressed vowels" (Hubbell 1950:90).

A second view is expressed by Bronstein (1960:179-180), who claims that unstressed vowels have undergone a historical weakening process, "so that they tended to level into, or toward, the /ə/ sound. This unstressing is still going on, so that not all unstressed vowels have levelled to /ə/". So the schwa sound may be spelled with any vowel, and its formation may approach the position of any other vowel from the central position of the mouth, with the articulators in neutral position.

A third view is Caffee's (1951) suggestion that each unstressed vowel is still psychologically related to a full vowel, even in the minds of illiterate speakers who are not influenced by orthography. Evidence of this is the ability of a speaker to pronounce an unstressed vowel as stressed for emphasis. This is

the tendency for the obtained formant frequencies of a vowel to fall short of the idealized target values for that vowel — those values that would be obtained if the vowel were produced in isolation resulting in an overall shrinking of the vowel space (Miller 1981).

Third view is a completely different view from the first one. This conflict justifies the acoustic test to resolve the quality of schwa. It will show whether it supports the first view or the third view. This is what the research question 1 concerns.

3. Methods

For the phonetic analysis, words with full vowels in stressed syllables and their derived words in which the same vowels will be reduced to schwa for the loss of stress were pronounced ten times each. Each word was placed in a sentence, "Say _____ again." The sentences were randomized so that the speaker would not know which vowel is tested. There was a total of 120 tokens. The F1 and F2 of each vowel were measured and plotted on the formant chart by the plotformant program developed by Ladefoged in UCLA. Each schwa derived from each full vowel was named t, v, w, x, y, z as shown in Table 1. The words were carefully chosen so that the measurement of F1 and F2 would be as accurate as possible. The best environment was found to be when the target vowel is between voiced obstruents. The subject named AMA was a female native English speaker who was born in Illinois.

Table 1 shows the words with full vowels in stressed syllable and the derived words in which the full vowels are reduced to schwa. In the formant chart each reduced vowel from each full vowel will be symbolized differently, i.e., the reduced vowel in *civility* is symbolized *t*, the reduced vowel in *stability* is symbolized *v*, etc., as shown in Table 1.

<Table 1> English Full Vowels and their Reduced Vowels with Symbols

Full vowels in stressed syllables	The reduced vowels in unstressed syllables in the derived words with symbols for each schwa
civil /ɪ/	civility /ə/ - t
stable /e/	stability /ə/ - v
definite /ɛ/	definitive /ə/ - w
battle /æ/	battalion /ə/ - x
revoke /o/	revocable /ə/ - y
botony /ɑ/	botanical /ə/ - z

For the phonological analysis, the schwa was tested with the framework of optimality theory. The constraints used to test the schwa were FAITH(V), *əV, FAITH V[-BACK+hiC], *V[-LOW, -TNS]#, REDUCE V[-STR, -TNS].

4. Analysis

The acoustic evidence of the reality of the schwa was compared with Ahn's (2000) study. In Ahn's (2000) study, the speaker named MATT was a male from the eastern United States. The speaker named AMA in this study was a female from Illinois. The acoustic data shows that it is universally true that there is a target in the schwa sounds each of which is derived from a full vowel. It has a tendency of converging toward a target around F1 500 and F2 1500. But there seems to be individual variations in the target according to the sex and dialects.

4.1. Phonetics of English Schwa

Figure 1 shows the formant chart with schwas plotted with the full vowels.

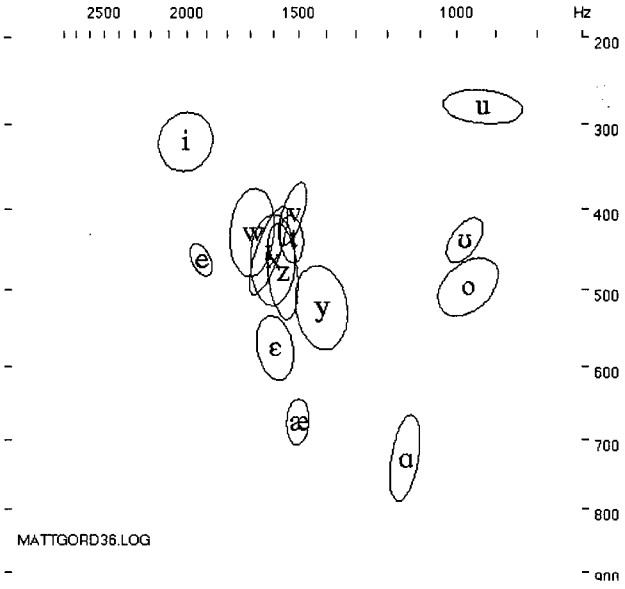

Figure 1. Formant chart for full vowels and the schwa sounds named t, v, w, x, y, z for the reduced vowel of ɪ, e, ɛ, æ, o, ɑ respectively (Ahn 2000)

In Figure 1, no consistent relationship was found between the full vowels and their reduced vowels in the unstressed syllables in their derived words. For instance, the *v*, *w*, *x* and *z* which are the derived schwas from the vowels /e/, /ɛ/, /æ/ and /ɑ/ respectively are not any closer to their original vowels. The *t* and its original full vowel /ɪ/ are very close, but this is not unusual because they both tend to centralize. Hagiwara's formant chart (Figure 6) verifies this point (1994:65, 67). It is not accidental that AMA's data show exactly identical positions of /i/ and /ɪ/ to both Matt's in Ahn (2000) and AMA's in the present study. The *y* which is the reduced vowel of /o/ is a little deviant from the group of other schwas, but its positions of F1 522 and F2 1419 in Ahn's 2000 study (Figure 1) and F1 631 and F2 1610 in AMA's data (Figure 3) overlaps the other schwas or are right adjacent to them while there is a

considerable distance from the original vowel /o/ in both Ahn's 2000 data and AMA's present data. So the case *y* does not provide a sufficient reason to reject the generalization that there is no relationship between the original full vowels and their reduced vowels.

Figure 2 shows a formant chart of full vowels ɪ, e, ɛ, æ, o, ɑ and their reduced vowels named t, v, w, x, y, z combined as one schwa /ə/.

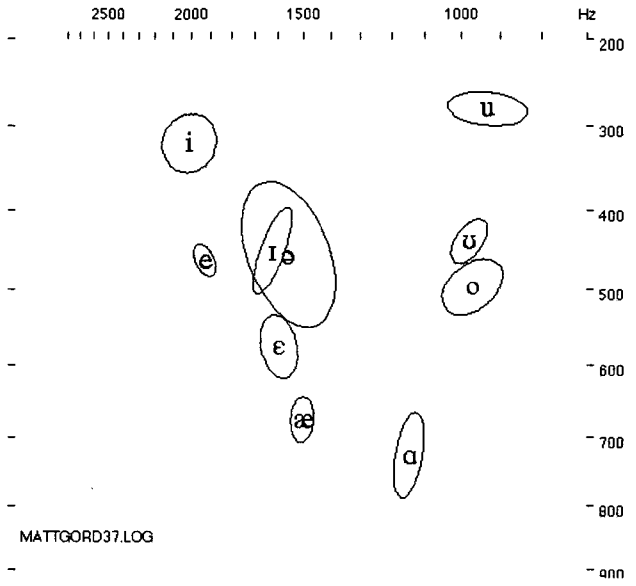

Figure 2. Formant chart for full vowels and reduced vowels t, v, w, x, y, z combined as /ə/ with the mean of F1 456 and F2 1560 (Ahn 2000)

In Figures 2 and 5, the combined /ə/ including *y* takes the idealized centralized position, the former having their mean point of F1 456 and F2 1560 and the latter having their mean point of F1 516 and F2 1815 as shown in Table 2. Their ideal target may be F1 500 and F2 1500, but there can be individual variations in their phonetic realization according to the

environment or personal physiological differences or dialects.

So the data support the first view mentioned above that schwa converges to a target which has a neutral, central position (Wallace 1994). As the data t, v, w, x, y and z in both Ahn's (2000) data and AMA's present data show, there might be an ideal target toward which each schwa converges, but in their actual realization it may fall short of the target. One specially noticeable thing is the similarity in Ahn (2000) and the present AMA's data which might add reliability of the data.

Figures 1 and 2 were compared with AMA's data in Figures 3, 4, and 5.

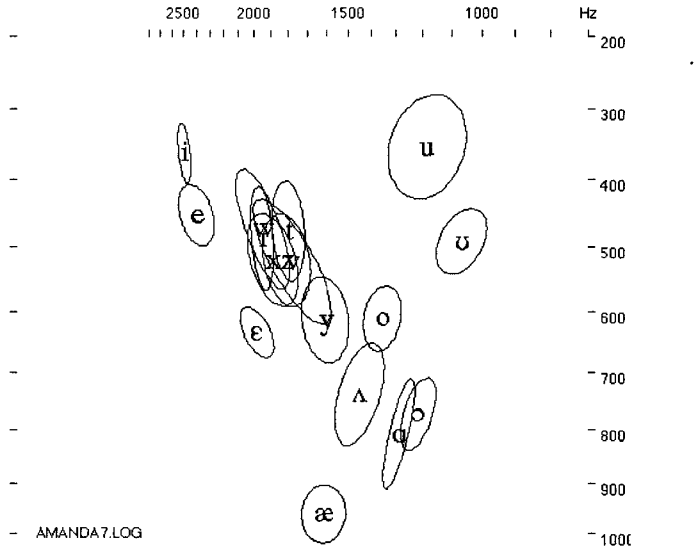

Figure 3. Formant chart for full vowels and the schwa sounds named t, v, w, x, y, z for the reduced vowel of ɪ, e, ɛ, æ, o, ɑ respectively (by AMA)

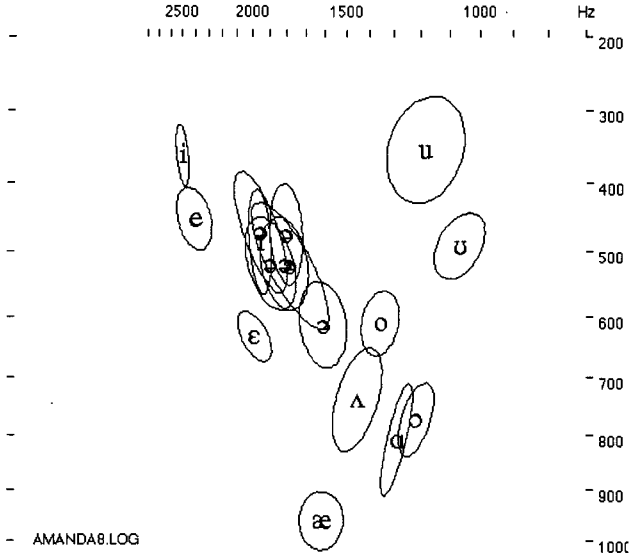

Figure 4. Formant chart for full vowels and reduced vowels t, v, w, x, y, z replaced by /ə/ (by AMA)

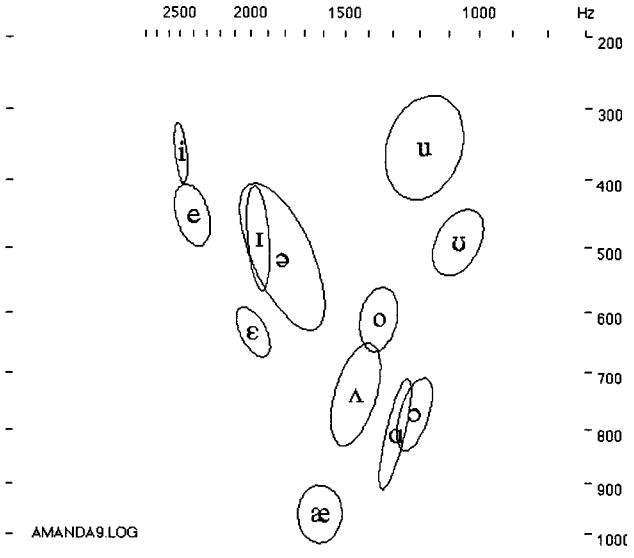

Figure 5. Formant chart for full vowels and reduced vowels t, v, w, x, y, z combined as /ə/ with the mean of F1 516 and F2 1815 (by AMA)

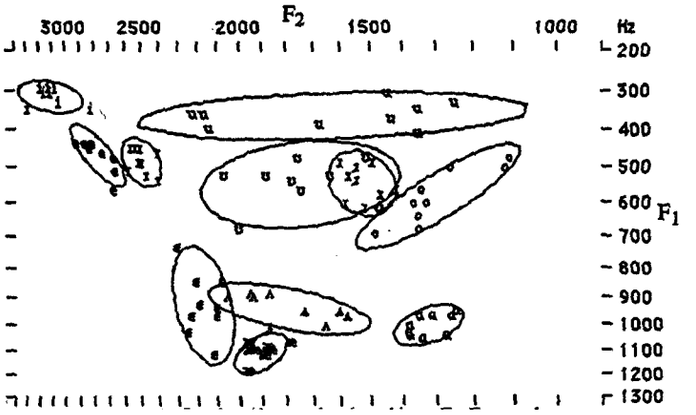

Figure 6. A vowel formant chart of an American speaker from Southern California (Hagiwara 1994:65). The vowel /ɪ/ is centralized further away from /i/ and closer to /e/.

<Table 2> The Means of F1 and F2 Value of the Reduced Vowel by Two Speakers

formants / speakers	F1	F2
Ahn (2000)	456	1560
AMA	516	1815

Findings:

(1) There was no relationship between the full vowels in the root words and their schwas in the derived words.

(2) The schwa sound *t*, *v*, *w*, *x*, *y*, *z* seemed to be centered around a target. The target seems to deviate a little from the ideal neutral tongue position depending on the speaker's sex and dialects.

4.2. The Phonology of English Schwa

In this section, schwa was explained by both rule-based grammar and constraint-based grammar. The difference was that

in rule-based grammar, rule-ordering was necessary, but in constraint-based grammar, rule-ordering was not necessary.

4.2.1. A Rule-Based Approach to Schwa

Three rules are necessary to explain the schwa phenomenon: Chomsky and Halle's Vowel Tensing Rule and Vowel Reduction Rule (1968:111) and a third rule as shown in (2).

(1) Vowel Tensing Rule

$$\begin{bmatrix} V \\ -stress \end{bmatrix} \rightarrow [+tense] \; / \; \left\{ \begin{bmatrix} \underline{\quad} \\ -low \end{bmatrix} \#, \; \underline{\quad}\, V \right\}$$

(2)

$$V \rightarrow ə \; / \; \begin{bmatrix} \underline{\quad} \\ -tense \\ -stress \\ <+back> \end{bmatrix} \begin{bmatrix} +cons \\ <+high> \end{bmatrix}$$

The [-stress, -tense] vowel before a [+high] consonant is reduced to schwa only if it is [+back] vowel.

(3) Vowel Reduction Rule

$$\begin{bmatrix} -stress \\ -tense \\ V \end{bmatrix} \rightarrow ə$$

Rule 2 is necessary to block the schwa rule application in the words in (4).

(4) *English, rèsignátion, tráffic, óstrich, márriage, Wéllington, pecúliar, Mónica, beguíle, ignóre, Africa*

But the unstressed vowels before [+high] consonants in (5) are

[+back] vowels, so they are reduced to schwa.

(5) *agó, adjácent, hýdrogen, phòtogénic, machíne, hávoc, Mónaco, ashóre, súrrogàte, eúnuchs, apólogy, ábacus*

To get the correct output, rule ordering is necessary. The rules needs to be applied in the order of (1), (2) and (3).

4.2.2. Constraints for the Schwa Rule

(1) Do not reduce the stressed syllables: **FAITH(V)**

The vowel is not reduced to schwa, when it has a primary or secondary stress.

/ɛ/: *cóntènt, cómmènt, tórmènt*

/ɛ/: *ínsèct, bísèct, cóntàct*

/ʌ/: *ádju'nct, ínco'me*

/ɪ, ɛ/: *línguist, hónest, témpest, látèx, èllípse, ásterisk*

/ɪ, ɛ/: *sýnonym, spéctrogràm, álmanàc, gýmnàst*

-prefix: the following prefixes attract secondary stress

- prefix+free morpheme: *ùnfínished, ùnfít, hỳperténsion, nòngénuine, àpolítical, prèdóminent, rèvíew,*
- polysyllabic prefix: *ànticlímax, sèmi-ánnual, còntradíct, ìnterfére, bìbliománia, hèliothérapy,*
- prefix+bound morpheme [-bk]: *distráct, deporta'tion, predíct, presérve*

-suffix:

- strong suffix: attract primary stress on itself.

-ade, -aire, -ation, -cation, -ee, -eer, -ese, -esque, -ette, -ier, -ific, -ina, -itis, -oon, -osis, -iferous

(2) Do not reduce a vowel before another vowel: ***əV**

ánnual, rádiàte, compánion, mániac, àrcheólogy

(3) Do not reduce [-back vowel] before a high consonant:

FAITH V[-back+hiC]

[-bkV+hiC] : Do not reduce to schwa.

párish, márriage, advántage, óstrich, tráffic, ignóre, Wéllington, pecúliar, pejórative, pélican, picánte, Mónica, beguíle

*-age is considered to be underlyingly [-ɪdʒ]

[+bkV+hiC] : Reduce to schwa.

agó, adjácent, hýdrogen, phòtogénic, aggréssive, machíne, hávoc, eúnuchs, Lúbbock, búttocks, ashóre, achíeve, pajáma, Mónaco

(4) Nonlow ([-Low]) vowels at the end of a word are tensed:

***V[-LOW, -TNS]#**

fiásco, éffigy, Híndu, cíty, háppy, potáto, véto

(5) Weak syllable: reduce to schwa: **REDUCE V[-STR-TNS]**

a. [ə]: *móment, pótent, mánagement, tórrent, éxcellent, rámpant, ínfant, sérpent, áccent*

b. suffix [+bk]: -al, -ous, -ia, -ium, -tion, -ary, -or, -er, -able

c. prefix [+bk]: *propóse, procláim, concíse, concéssion, consérve*

Using five constraints, seven words, *Katera* (name of a new model car by GM), *peculiar, hydrogen, tupi, climax, comment* and *moment* were tested.

<Table 3> The Constraint Table

Constraint Name	Abbreviation
DO NOT REDUCE THE STRESSED VOWEL	FAITH(V́)
DO NOT REDUCE A VOWEL BEFORE ANOTHER VOWEL	*əV
DO NOT REDUCE A [-BACK] VOWEL BEFORE A [+HIGH] CONSONANT	FAITH V[-BACK+HiC]
TENSE A NONLOW VOWEL AT THE END OF A WORD	*V[-LOW, -TNS]#
REDUCE UNSTRESSED AND UNTENSED VOWEL	REDUCE V[-STR, -TNS]

Tableaus (6), (7), (8), (9), (10), (11), (12) are the results of the test with these constraints.

(6)

/katéra/	FAITH(V́)	*əV	FAITH V [-BACK+HiC]	*V[-LOW, -TNS]#	REDUCE V [-STR,-TNS]
☞ katérə					
katéra					*!
katérə					*!
katéra					*!*
katérə	*!				

The form /katérə/ is considered to be the underlying form. The candidates, /kətéra/, /katérə/, /katéra/ are ousted by the constraint REDUCE V[-STR, -TNS] and /kətérə/ is ousted by the constraint FAITH(V́). The form /kətérə/ becomes the correct output.

(7)

/pɪkjúlɪa/	FAITH(V)	*əV	FAITH V [-back+HiC]	*V[-LOW, -TNS]#	REDUCE V [-STR, -TNS]
☞ pɪkjúlɪə					
pəkjúlɪə			*!		
pɪkjúləə		*!			
pɪkjúləa		*!			*
pɪkjólɪa	*!				*
pəkjólɪə	*!		*		

(8)

/háɪdrodʒɛn/	FAITH(V')	*əV	FAITH V [-BACK+HiC]	*V[-LOW, -TNS]#	REDUCE V [-STR, -TNS]
☞ háɪdrədʒən					
háɪdrədʒɛn					*!
háɪdrodʒən					*!
háɪdrodʒɛn					*!*
hə́ɪdrədʒən	*!	*			
hə́ɪdrodʒɛn	*!	*			**

(9)

/túpi/	FAITH(V')	*əV	FAITH V [-back+HiC]	*V[-LOW, -TNS]#	REDUCE V [-STR, -TNS]
☞ túpi					
túpə				*!	
tə́pi	*!				
təpə	*!			*	

(10)

/kláɪmæks/	FAITH(V')	*əV	FAITH V [-BACK+HiC]	*V[-LOW, -TNS]#	REDUCE V [-STR, -TNS]
kláɪmæks					
kláɪməks	*!				
kləɪmæks	*!	*			
kləɪməks	*!*	*			

(11)

/kámɛnt/	FAITH(V')	*əV	FAITH V [-back+HiC]	*V[-LOW, -TNS]#	REDUCE V [-STR, -TNS]
kámɛnt					
kámənt	*!				
kəmɛnt	*!				
kəmənt	*!*				

(12)

/móməɛnt/	FAITH(V')	*əV	FAITH V [-BACK+HiC]	*V[-LOW, -TNS]#	REDUCE V [-STR, -TNS]
mómənt					
mómɛnt					*!
mómənt	*!				
mómɛnt	*!				*

The analysis by the optimality-theoretic tableaus (6), (7), (8), (9), (10), (11), (12) produced the correct output of all the seven words. No rank was found and the violation of any one of the constraints ousted the candidates.

5. Conclusions

The schwa phenomenon in English is supported both phonetically and phonologically. In the phonetic analysis no relationship was found in the distribution of the F1 and F2 of the full vowels and their reduced vowels in the unstressed syllables of the derived words either in Ahn's (2000) study or in speaker AMA's case in this study. The reduced vowels tended to converge into a possible target of F1 500hz and F2 1500hz in the case of Ahn's (2000) study. But in the speaker AMA's case, the distribution of the reduced vowels were converging to a target but to a slightly different target the average mean point of which was F1 516 and F2 1815. So the view that the schwa sounds derived from different full vowels converge into a target is supported. It seemed that the target point of the schwas is slightly different individually according to sex or dialects, but that their centering tendency was universal.

Phonologically it was successfully explained that the schwa phenomenon is systematic in English. The optimality-theoretic tableaus gave the correct output using FAITH(V), *əV, FAITH V[-BACK+HiC], *V[-LOW,-TNS]#, REDUCE V[-STR,-TNS] as constraints. The advantage of using the optimality tableaus was that it doesn't have to use the order among the rules. The ranking was not found, but a violation of any of the constraints ousted the candidates.

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