Variable Schwa Deletion in English: A Corpus Study*

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Song, Jieun. 2013. Variable Schwa deletion in English: A corpus study. *Studies in Phonetics, Phonology and Morphology* 19.1. 33-52. This study investigates schwa deletion in American English using the Buckeye Corpus. To determine the contributions of grammatical (e.g., sonority of onset clusters) and non-grammatical (e.g., lexical frequency) factors to schwa deletion, the distribution of schwa-deleted word forms is examined in terms of phonological, morphological, and lexical environments. As expected, schwa deletion occurred more frequently in post-stressed environments than in pre-stressed environments. Of all the factors, the most significant factor affecting deletion rates in the post-stressed environment was the sonority profile of onset clusters that arise after deletion: deletion rates are higher when the prospective consonant cluster forms a sonority rise (large rise and small rise) than when it forms a sonority fall. The results show that the Sonority Sequencing Principle alone cannot explain the observed patterns of variable schwa deletion. This paper suggests that schwa deletion rates are modulated by English speakers' knowledge of the universal sonority preferences. The nature of this knowledge regardine sonority preferences will be further discussed. **(Seoul National University)**

Keywords: phonological variation, schwa deletion, sonority, word frequency, Buckeye Corpus

1. Introduction

This paper investigates schwa deletion in American English, which is a variable phonological process: a schwa vowel /ə/ in an unstressed syllable in English words undergoes deletion optionally as in *family* [ˈfæməlɪ~ˈfæmlɪ] or *separate* [ˈsɛpəɹɪt~ˈsɛpɹɪt].

It has been acknowledged in previous research that schwa deletion occurs when the onset consonant cluster that results from schwa deletion forms a sonority rise such as /fl/ and /kl/ in *buffalo* [ˈbʌfloʊ] and *chocolate* [ˈtʃɔklɪt], respectively (e.g., Hooper 1978). However, it has also been noted that phonotactic legality cannot fully explain patterns of observed schwa deletion at least in the word-initial position (e.g., Davidson 2006). One of the major goals of this study is to illuminate the phonological factor conditioning schwa deletion. To this end, this paper will also assess the role of fine-grained knowledge of sonority preferences exploited in perception (Berent et al. 2007) in determining the frequency of schwa deletion.

Another factor of schwa deletion is related to the locus of deletion.

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Patterson et al. (2003) found that schwa deletion is much more likely to occur in post-stressed environments (i.e. when the target schwa follows a stressed syllable) than in pre-stressed environments (i.e. when the target schwa precedes a stressed syllable). However, it is still not clear why such a discrepancy arises between the two environments.

In addition, non-grammatical factors are worthy of attention to explain patterns of variable schwa deletion in English. Specifically, the effect of lexical frequency on schwa deletion rates has received some attention in previous studies (e.g., Hooper 1976). According to the previous studies, it is expected that higher frequency words undergo schwa deletion to a greater extent than do lower frequency words, while Patterson et al. (2003) have found only minor effects of lexical frequency on deletion rates. Each of these factors will be discussed in more detail in the following sections from 1.1 to 1.5.

The present study will investigate these factors affecting the propensity for schwa deletion in a large data of conversational speech. Admittedly, there have been a few previous attempts to examine the distribution of schwa-deleted variants in speech databases, focusing on the influences of such factors on deletion rates such as Patterson et al. (2003) and Ryu and Hong (2011)[1]. However, the present study mainly focuses on clarifying the unresolved questions briefly introduced above, with an emphasis on the phonological factor. Most importantly, this study reveals that schwa deletion is conditioned by English speakers' fine-grained knowledge of the universal sonority preferences. Furthermore, this study aims to shed light on the difference in the schwa deletion process depending on stress environment.

1.1 Phonological variation in conversational speech

Speech sounds often undergo some phonological processes when certain conditions are met. For instance, assimilation is a widely observed phonological phenomenon in many languages. Phonological processes have been studied in the field of phonology with respect to how they occur in terms of the application of rules or constraint interactions in generative grammar. However, pronunciation variation in language seems far more pervasive than acknowledged in early phonological theories. First of all, many phonological processes are applied optionally and conditioned not only by grammatical factors such as phonological environments, but by non-grammatical factors such as rate of speech or speaking styles. Furthermore, as Johnson (2004) suggests, massive reduction in casual speech is only a natural and regular feature of language. In the ViC corpus (Buckeye Corpus)

[1] I discovered that Ryu and Hong (2011) had also examined the factors of schwa deletion in the Buckeye Corpus, specifically, word frequency, stress environment, and the sonority condition before this study was conducted. However, the focus and results differ between the two studies.

that he analyzed, a significant portion of the words are realized with one or more phonemes deviated or deleted from their citation forms. One of the important questions that have received a lot of attention in psycholinguistic research is how phonological variants that are produced differently from their citation forms are processed in word recognition (e.g., Connie 2004, Connie et al. 2008).

While the variability in the phonetic realization of speech often challenges traditional premises of phonological theories, it can also enhance our understanding of phonological variation. For example, attempts are being made to find ways to explain phonological variation in generative grammar and to incorporate external factors such as lexical frequency or speaking styles into generative models. Coetzee (2009) proposed an integrated grammatical/non-grammatical model of phonological variation. To incorporate the contribution of non-grammatical factors, especially that of lexical frequency to t/d deletion into his model of Harmonic Grammar (HG), he suggested the weight scaling method, whereby the weight of faithfulness constraints is scaled down for high frequency words and up for low frequency words, so that the deletion occurs more frequently in high frequency words. Furthermore, many researchers now use large speech databases, especially those containing speech produced in a conversational style, to investigate the phonetic variability of speech. Speech produced in a casual speaking style is more likely to contain a wider variety of phonological and phonetic variation than in read speech. Hence, this study will use a large corpus of conversational speech to observe the patterns of schwa deletion found in spontaneously produced, casual speech. This study used the Buckeye Corpus (Pitt et al. 2007), which is a collection of spontaneous speech of American English recorded at the Ohio State University. The speech was obtained through interviews with 40 native speakers of American English from Central Ohio. The corpus contains approximately 300,000 words which were mostly used to express the speakers' opinions about everyday topics.

1.2 The markedness of sonority profiles

Phonological conditions for schwa deletion in English have been discussed in early descriptive studies such as Zwicky (1972) and Hooper (1978). According to those early studies, the most significant conditioning factor of schwa deletion is related to sonority profiles of onset clusters that result from schwa deletion. Specifically, a schwa vowel deletes readily when it is followed by r, l, and n, while schwa deletion rarely occurs before m[2] and never before obstruents. For instance, words like *sep<u>ar</u>ate*, *hist<u>ory</u>*,

[2] Zwicky (1972) provides no explanation for this observation. However, Hooper (1978) assumes that this is because /m/ is less sonorant than /n/. She also presents a few cases where deletion occurs before /m/, especially when /s/ precedes the target schwa, such as *hand<u>som</u>er, blo<u>ssom</u>ing, de<u>cim</u>al,* and *spe<u>cim</u>en.*

misery, *camera*, *desolate*, *javelin*, *finally*, and *personal* allow schwa deletion in their second syllables, whereas words like *ultimate*, *rocketing*, *balloting*, *monitor* do not. Hooper (1978) also suggests that this particular restriction on schwa deletion is not English-specific phonotactic grammar, but a "universal syllable structure condition". Thus, the process has not touched words that create clusters of /s/ plus a voiceless stop as in *gossiping*, although they are perfect English onsets. This principle can also be referred to as the 'Sonority Sequencing Principle'.

(1) SON-SEQ (Clements 1990)
Complex onsets rise in sonority, and complex codas fall in sonority

The onset sequences consisting of an obstruent followed by r, l, or n, or a nasal followed by a liquid do not violate the Sonority Sequencing Principle since they rise in sonority, while the onset sequences of an obstruent followed by another obstruent violate the SSP since they do not rise in sonority.

On the other hand, there are reasons to believe that the Sonority Sequencing Principle may not fully explain the patterns of schwa deletion. This is especially true in the word-initial environment. For example, schwa deletion in this position in *potato* or *potential* creates an illegal English onset cluster /pt/. Davidson (2006) found that pre-tonic schwa elision is not constrained by phonotactic legality, in that pre-tonic elision is a gestural overlap rather than phonological deletion. Glowacka (2001) also suggests that sonority distance principles do not determine the shape of resulting consonant clusters in British English in both word-initial and word-medial positions. She reported that schwa deletion in British English produced illegal medial consonant clusters: *beautiful, seventeen, information*[3]*, Mexico, company* and so forth. Since Patterson et al. (2003) had not investigated the effect of the sonority condition in their corpora analysis, this paper aims to determine the role of the Sonority Sequencing Principle as a conditioning factor of schwa deletion in a corpus.

Berent et al. (2007) investigated English speakers' sensitivity to the sonority of onset clusters. Although they did not deal directly with the schwa deletion process, it adds greatly to our understanding of English speakers' phonological knowledge of the sonority of onset clusters. They suggest that English speakers are equipped with universal preferences about the sonority of onset clusters, which allows them to exhibit sensitivity to the sonority of even "unattested" onset clusters in perception. For instance, in the syllable count judgment task, English speakers performed more accurately with sonority rises such as "bnif" than with sonority plateaus such as "bdif", which, in turn, they performed more accurately with than sonority falls such as "lbif". Their findings differ from other theories stating that phonological

[3] Since British English is a non-rhotic variety, the consonant cluster produced in *'information'* is /fm/.

knowledge is explicable in terms of statistical properties of the lexicon without any abstract grammar. Specifically, Dell et al. (2000) carried out speech error elicitation experiments with English speakers. Speech errors that the speakers produced have shown that they can learn new phonotactic constraints in adulthood even during a short period of time. According to them, this learning process takes place by experiencing sound sequences and storing them in memory.

This paper will examine schwa-deleted words found in the Buckeye Corpus and investigate the phonological environments of the words. One of the major goals of this paper is to investigate how the Sonority Sequencing Principle affects the patterns of schwa deletion in American English. Alternatively, the role of phonological knowledge regarding universal sonority preferences will also be examined. In other words, if the phonological distribution of schwa-deleted word forms is consistent with English speakers' sonority preferences found in Berent et al. (2007), which is that small rises are more acceptable than plateaus, which in turn, are more acceptable than falls, a new conclusion can be drawn: schwa deletion in English is conditioned by more fine-grained universal markedness about the sonority of onset clusters.

However, it is important to note that Berent et al. (2007) also mention that English speakers might be exposed to such unattested onset clusters in schwa-reduced forms in fast speech and the familiarity with such onset clusters could lead to the sonority-related preferences, although they argue that previous research does not support this hypothesis. If the distribution of schwa-deleted variants in this study follows the universal sonority-related preferences, conversely, this might suggest that the phonetic variation found in conversational speech can account for English speakers' sonority preferences. This possibly suggests that English speakers' statistical knowledge about sound patterns can also play some role in shaping the sonority preferences as proposed in Dell et al. (2000).

1.3 Lexical Stress

Patterson et al. (2003) analyzed the distribution of schwa-deleted word forms found in two conversational speech corpora to investigate factors affecting the propensity of schwa deletion. First, they used the Switchboard speech database (Godfrey et al. 1992) containing approximately 2400 two-sided telephone conversations produced by 543 speakers from all areas of the United States. In addition, they built the Narrative Corpus which was designed to include words of interest for their schwa deletion research. 105 participants[4] from an area of New York were recorded talking about twenty short stories that they had read. The stories contained 71 target words in total and the participants repeated the target words while discussing the stories

[4] They reported that 54 students from Binghamton University in Binghamton, New York, had participated in the recordings with friends that they brought with them.

with their partners. Among 2,318 word tokens available for analysis, there were 850 schwa-deleted tokens. The results revealed that the most significant factor affecting schwa deletion rates was the lexical stress environment. They found that a schwa is more likely to be deleted in post-stressed environments (e.g., *buffalo*, *personal*) than in pre-stressed environments (e.g., *collect, connected*).

It has also been suggested in previous research that vowel deletion in pre-stress and post-stress positions is qualitatively different. Kager (1997) argues that there are two types of rhythmic vowel deletion, namely, gradient and categorical deletion. To be specific, pre-stressed vowels in iambic words are phonetically reduced to preserve the weak syllable in the iamb, whereas post-stressed vowels in trochaic words are phonologically deleted, thereby destroying syllabicity. The difference in schwa deletion rates in English depending on the stress environment may be related to this typological pattern of vowel deletion.

In a similar vein, previous research also suggests that other phonetic aspects have an influence on whether or not deletion occurs in the word-initial position. Specifically, Davidson (2006) suggests that acoustic characteristics and articulatory patterns of resulting consonant clusters can better explain the observed patterns of elision than phonotactic legality, assuming that pre-tonic schwa deletion is increased gestural overlap. For instance, elision occurs most frequently in s-initial words and /l/-second words because the gestures of /s/ easily overlap the gesture for a schwa, and because /l/ is not easily distinguished from the preceding schwa.

In attempts to elucidate the effect of the lexical stress environment, this study will investigate whether the various factors of schwa deletion, especially the sonority condition, have dissimilar influences in the two environments.

1.4 Lexical frequency

Non-grammatical factors such as speech register, dialects, and usage frequency can also affect the application of a variable phonological process. Previous research has shown that word frequency, in particular, affects many variable phonological processes such as t/d deletion in English (e.g., Bybee 2000) and Japanese devoicing (Kawahara 2011). Basically, higher frequency words are more likely to undergo an optional phonological process than lower frequency words. One of the premises underlying the usage-based model (Bybee 2000) is that high-frequency words and phrases have stronger representations since they are more easily accessed, relative to low-frequency words that are more difficult to access. According to this model, sound change is also conditioned by language use.

Similarly, it has been suggested by Hooper (1976) and Bybee (2000) that high-frequency words undergo schwa deletion to a greater extent than do low-frequency words. For instance, *memory*, *salary*, and *summary* are more likely to go through the deletion process than *mammary*, *celery*, and *summery*, respectively. In contrast to what has been suggested by Hooper (1976), Patterson et al. (2003) have found only small effects of word frequency on schwa deletion in conversational speech corpora. In the Switchboard Corpus, the lexical frequency factor led to a very small increase in predictability of schwa deletion rates in their logistic regression model (ß=-0.001, SE=0.0003, p<.01). In the Narrative Corpus, the lexical frequency factor also had a minimal effect on the model (ß=-0.003, SE=0.0007, p<.01). They did not find any significant effects of lexical frequency when separate models were run depending on lexical stress environments.

Since the previous studies are inconsistent with one another with respect to the influence of lexical frequency on schwa deletion, one of the objectives of this study is to determine whether or not schwa deletion occurs in high-frequency words more frequently than in low-frequency words, by examining a large corpus of conversational American English.

1.5 Other factors

It can be hypothesized that morphologically complex words resist schwa deletion to a greater extent than morphologically simple words, since the presence of a morphological boundary can serve as a constraining factor on the operation of the rule (Guy 1991). In fact, Patterson et al. (2003) examined whether morphological complexity influenced deletion rates. Their corpus had 3-syllable complex words, such as *correct-ing*, *pollut-ing*, *pollut-ed*, and *correct-ness*, and 3-syllable simple counterparts, such as *corolla*, *ferocious*, *subpoena*, and *forensic*. Deletion rates in the two environments were not significantly different. This is not a surprising result since the morphological boundary is far from the target schwa, which is in the first syllable in those words. The present study will investigate whether morphological complexity could play a role in determining schwa deletion rates. In this study, words in which a schwa is deleted at the morphological boundary, such as *dispos-able* and *notice-able,* were labeled as morphologically complex words. It is probable that deletion rates are lower in those complex words than in simple words.

Lastly, word length was included as well in the models to explore the influence of word length on deletion dates. Previous studies suggest that longer words are more likely to tolerate variation than shorter words (e.g., McClelland and Elman 1986).

2. Methods

Schwa-deleted words were found in the Buckeye Corpus. They were searched by running a Praat script that was designed to compare the number of a schwa in the word's CMU pronunciation with that in its transcribed pronunciation[5]. Since the search was performed based on the Buckeye transcription, the transcribers' judgments were used as a primary criterion in determining whether a schwa is deleted or not. However, additional steps were required. The script was made user-friendly, in that every time a word is found through the search, the spectrogram of that word pops up in the editor window along with its transcriptions for verification. This process was necessary because the script also found numerous cases where a schwa vowel in the canonical pronunciation was realized as some other vowel such as /ɪ/ in the corpus. Those were not counted as schwa-deletion cases. Afterwards, those counted as schwa-deleted words were briefly re-checked both auditorily and acoustically by the author to verify whether deletion really occurred as indicated in the transcriptions. In uncertain cases, the spectrogram was carefully examined to see if any vocalic portion with formant structure remains. Sometimes, the amount of high-frequency energy was also considered to differentiate between liquids and vowels[6]. There were a few words in which the gesture of a schwa seemed to remain in neighboring sounds such as "*politicians*". However, articulatory gestures are beyond the scope of this paper, so the final decisions were made based on auditory and acoustical criteria only. It is important to note that the transcriptions of the Buckeye Corpus were used as the most important source for judgment. This seems to be reasonable, considering that the Buckeye transcriptions were made by several phonetically trained transcribers using very detailed labeling conventions (Kiesling et al. 2006).

As a result, a total of 733 schwa-deleted word forms were found and their phonological/morphological environments and lexical characteristics were carefully examined to develop quantitative models. In addition, the number of deletions and deletion rates were calculated for each word type found. Deletion rates were calculated by dividing the total number of occurrences of each word in the Buckeye Corpus[7] by the number of occurrences of schwa deletion of that word. Deletion rates will provide a more accurate measure of the frequency of schwa deletion than mere numbers of schwa deletions, since the number of schwa deletions for each word will differ greatly depending on what the speakers talk about in a particular context. With regard to consonant combinations created after deletion, sonority profiles and the number of consonants in a cluster were labeled. To express the sonority distance between the first and second consonants, the sonority scale was used as shown in (2). The sonority score of the second consonant was subtracted from that of the first consonant. For instance, large rises as in 'blif' and small rises as in 'bnif' have positive values of the sonority distance, namely 3 and 2, respectively, whereas plateaus as in 'bdif' have 0 and falls as in 'lbif' have negative values, -3, in this particular case.

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[5] This script was created by Prof. Kyuchul Yoon and can be downloaded from his website (http://www.ling.ohio-state.edu/~kyoon/).
[6] Liquid sounds are characterized by low energy in high-frequency regions.
[7] This is also provided in Prof. Kyuchul Yoon's script archive.

(2)
Vowels/Glides (5) Liquids (4) Nasals (3)[8] Fricatives (2) Stops (1)
← More sonorous Less sonorous →

In addition, word frequency and word length of each schwa-deleted word and the stress-position of each deleted schwa were labeled. To obtain word frequency, the Corpus of Contemporary American English (COCA; Davies 2010) was used. COCA is a large and balanced corpus of American English, which contains more than 450 million words equally obtained from spoken, fiction, popular magazines, newspaper, and academic texts written from 1992 to 2012.

3. Results

All statistical analyses in this study were performed in R version 2.15.2. First of all, inter-speaker variability was investigated. A one-way ANOVA[9] was performed to investigate whether schwa deletion rates differ for different speakers. Speaker type (i.e. each of the 40 speakers) was used as an explanatory variable and the number of deletion cases for each speaker as a response variable. It was found that the speaker variable was not a significant factor determining schwa deletion ($F(1, 38)=0.162$, $p=0.69$). It can therefore be concluded that inter-speaker variation is negligible in this study.

Secondly, the effect of word type was investigated. 185 word types were found in the search. Among the words, there were *Columbus, definitely, interested, necessarily, personally, responsibility, businesses, spiritual, Florida, national* and *miserable* which had undergone schwa deletion more than 10 times in the corpus. Deletion rates of these words are higher than 40%. There are some words which had undergone deletion several times, but the rate of deletion is actually not as high. In contrast, there were *philosophy, horrible, limited, original, available, animal, director, forever, traditions, supported, potential, position, conservative, connected, communications, collections, denominations,* and *evidence* which had undergone schwa deletion only once in the corpus. Those are the words whose deletion rates were lower than 20%.

The effect of stress environment was investigated in a one-way ANOVA. As expected, the influence of stress on deletion rates was significant ($F(1, 232)=6.606$, $p<.05$). The mean deletion rates of pre-stressed and post-stressed environments were 37.53 % and 55.50 %, respectively and the numbers of deletions of pre-stressed and post-stressed environments were 177 and 556, respectively. The boxplot and descriptive statistics of deletion

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[8] Despite Zwicky (1972)'s argument on the status of /m/, this study treated /m/ and /n/ as both being classified as Nasal (3).

[9] Tests of normality and tests of equal variances were unnecessary in this study, since the size of each group tested was very large. It is normally assumed that no such tests are required for a group of more than 30 cases.

rates depending on stress environments are presented in Figure 1 and Table 1. The influences of other factors on deletion rates were assessed for each stress environment.

Figure 1. Deletion rates of stress environments

Table 1. Descriptive statistics of deletion rates of stress environments

Stress Environment	Mean	Median	Min	Max	Standard Deviation
Pre-stressed	37.53	50.00	1.79	100	31.51
Post-stressed	55.50	16.67	3.45	100	34.71

First, the sonority factor was investigated by conducting one-way ANOVAs. It was found that the sonority of onset clusters significantly affects deletion rates in the corpus (F(6, 194)=3.192, p<.01). Tukey post hoc tests found that the sonority distances '1' and '3' are significantly different from the distance '-3' (p<.01). When one-way ANOVAs were run separately for pre-stress and post-stress data sets, the results showed that the sonority distance of onset clusters affects deletion rates only in the post-stress position (F(6, 171)=3.846, p < .01). Tukey post hoc tests found that the sonority distances '1', '2', and '3' are significantly different from the distance '-3' (p<.01, p<.05, and p<.001, respectively). In contrast, the sonority distance was not a significant factor affecting deletion rates in the pre-stressed environment.

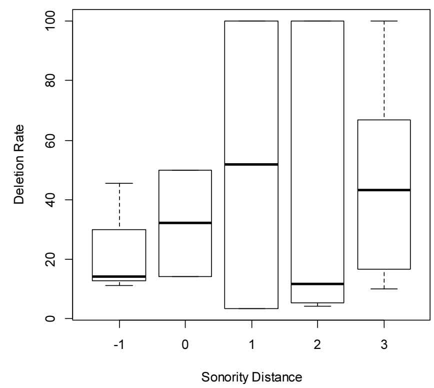

Figure 2. Sonority effects in the pre-stressed environment

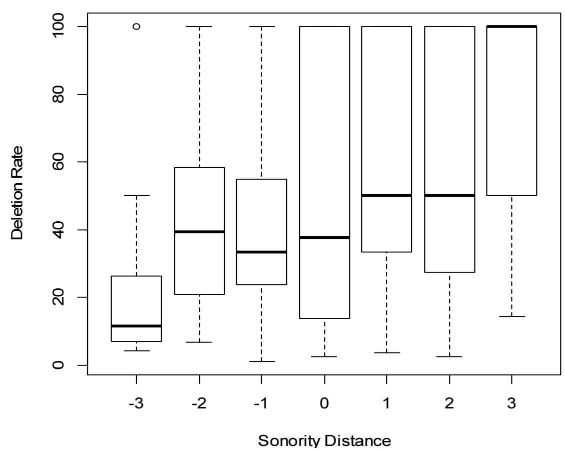

Figure 3. Sonority effects in the post-stressed environment

Table 2. The mean deletion rates in the post-stress position

Sonority Distance	Mean Deletion Rate
-3	22.470
-2	43.690
-1	45.370
0	48.640
1	58.970
2	55.670
3	73.990

These findings were derived from schwa deletion rates for each word type[10]. Although deletion rates seem to provide a more accurate measure of the frequency of deletion than the number of deletions, it is still necessary to compare the number of deletions at different levels of sonority distance. A table is presented with deletion counts for each category of the stress environment and the sonority distance in Table 3.

Table 3. Schwa deletion counts depending on the stress environment and the sonority distance

	-3	-2	-1	0	1	2	3	total
Pre-stressed	0	0	7	5	2	9	154	177
Post-stressed	39	42	112	39	157	144	23	556

In the pre-stressed environment, 154 of the schwa-deleted words had the sonority distance 3. Among them, 136 cases were from one word type *"Columbus"*. The word frequently appeared during the interviews for many of the speakers since they lived in Columbus. Regardless, it seems difficult to obtain any significant statistical findings in the pre-stressed environment due to the small number of deletions found in this position.

To investigate the contribution of sonority-based onset markedness to the propensity to delete a schwa, additional analyses were conducted. The sonority distances from -3 to 3 were reclassified as fall, plateau, small rise and large rise. A one-way ANOVA shows that the sonority profile is a significant factor of schwa deletion in the corpus ($F(3, 197)=4.697$, $p<.01$). Tukey post hoc tests found that the mean deletion rates of large rises and that of small rises are significantly different from that of falls ($p<.05$ and $p<.01$, respectively). In addition, one-way ANOVAs separately run for each stress environment suggest that the sonority profile significantly affects deletion rates in the post-stress position ($F(3, 174)=5.873$, $p<.001$), but not in the pre-stress position. Tukey post hoc tests also revealed that the mean deletion rates of large rises and that of small rises were significantly different from that of falls ($p<.01$) in the post-stress position. The boxplot and descriptive statistics of deletion rates depending on sonority profiles are presented below.

[10] In fact, there were some cases in which more than one cluster type was found for one word type. For instance, in the word "*organizations*", the second vowel or the third vowel was deleted, giving rise to the clusters /gn/ and /nz/, respectively. In such cases, deletion rates were derived from each cluster type separately.

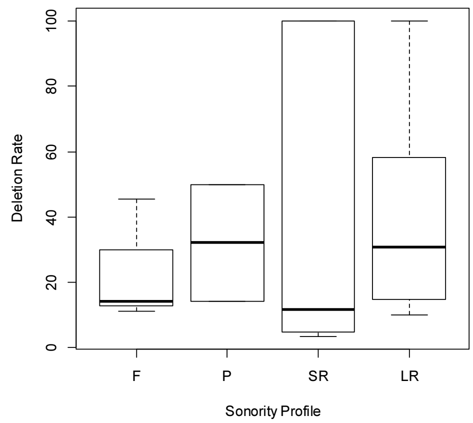

Figure 4. Deletion rates of sonority profiles in the pre-stressed environment (F:fall P:plateau SR:small rise LR:large rise)

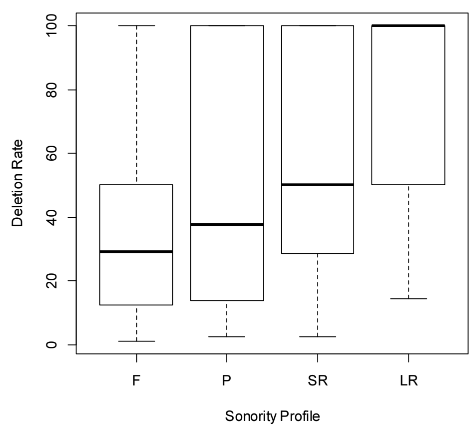

Figure 5. Deletion rates of sonority profiles in the post-stressed environment (F:fall P:plateau SR:small rise LR:large rise)

Table 4. Descriptive statistics of deletion rates depending on sonority profiles in the post-stressed environment

Sonority Profile	Mean	Median	Min	Max	Standard Deviation
Fall	39.10	28.99	1.11	100.00	32.03
Plateau	48.64	37.50	2.50	100.00	39.21
Small Rise	57.70	50.00	2.50	100.00	33.74
Large Rise	73.99	100.00	14.44	100.00	31.41

Table 5 shows deletion counts for each category of the stress environment and the sonority profile. While the mean deletion rate of falls in the post-stressed environment was significantly lower than that of rises, its number of deletions was quite large.

Table 5. Schwa deletion counts depending on the stress environment and the sonority profile

	Fall	Plateau	Small Rise	Large Rise	total
Pre	7	5	11	154	177
Post	193	39	23	301	556

In addition, regression analyses were performed with the rate of deletion as a response variable and word frequency as an explanatory variable. Instead of raw frequencies, the log of the frequency was used in the analyses. When deletion rates were used as the response variable of the model, word frequency was found to be a significant predictor in both pre- stress and post-stress models. However, the b-values were negative, which shows that there was a negative relationship between deletion rates and word frequency (Pre: b= -19.699, $p<.001$; Post: b=-10.244, $p<.001$). It means that schwa deletion is more likely to occur in low frequency words than in high frequency words, which is completely against the hypothesis, as well as what previous studies have suggested. However, these results need to be interpreted with caution. If the number of occurrences of a word in the Buckeye Corpus and its COCA frequency are inherently correlated with each other, the increase of word frequency may negatively affect deletion rates, as the Buckeye frequency, which is the denominator of the deletion rate, also increases.

To provide a more accurate evaluation of the influence of lexical frequency, the number of deletions entered the models instead as an explanatory variable. It was revealed that word frequency is a significant predictor of schwa deletion only in the post-stressed environment (b= 1.0384, $p<.001$, R-squared=0.09367; $F(1, 160)=16.54$, $p<.001$). The positive b-value indicates a positive relationship between word frequency and the number of deletions, corroborating the hypothesis that schwa deletion affects words of high frequency more than those of low frequency. However, this also needs to be interpreted carefully. It is probable that the number of deletions of a word were affected by the word's number of occurrences in the corpus, in other words, the Buckeye frequency. In addition, the Buckeye frequency is significantly correlated with the COCA frequency (Pearson's correlation coefficient: 0.54, $p<.001$). Therefore, partial correlation was conducted using "ppcor" package in R to obtain the correlation between word frequency i.e. the COCA frequency and the number of deletions, while controlling for the effects of the Buckeye frequency. As a result, word frequency effects were found to be significant in determining schwa deletion rates in the post-stressed environment ($p < .001$). However, the b-value was -.26, which again shows a negative relationship between word frequency and schwa deletion.

To conclude, it seems very difficult to determine the contribution of word frequency exactly in this speech database. To some extent, the statistical analyses converge on the conclusion that word frequency acts as a significant factor in post-stressed environments. However, the negative relationship between word frequency and schwa deletion found in some of the analyses complicates the prediction of this study.

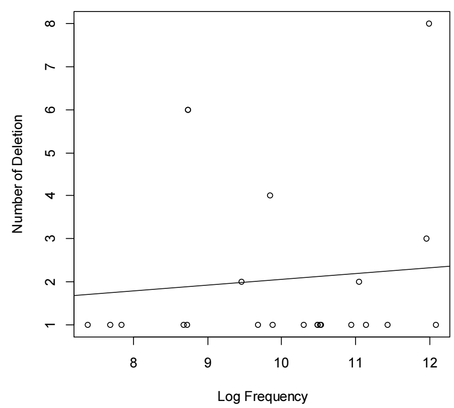

Figure 6. Lexical frequency effects in the pre-stress environment

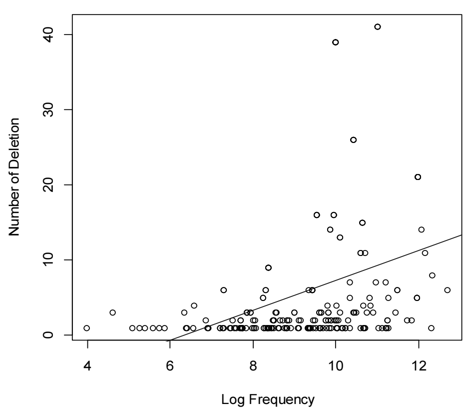

Figure 7. Lexical frequency effects in the post-stress environment

More regression analyses were performed to explore the influence of other factors. No significant effects of word length were found either in the pre-stressed or post-stressed environments. Table 6 provides deletion counts depending on word length. Although no significant statistical results were found, there was a slight tendency for longer words to have higher deletion rates than shorter words. The large number of deletions in 3-syllable words in the pre-stressed position is due to the word *"Columbus"* whose deletion cases appeared 136 times.

Table 6. Schwa deletion depending on word length

	3-syll	4-syll	5-syll	6-syll	7-syll
Pre-stressed (Number/Rate%)	152/29.21	21/39.91	3/52.08	1/100	0/0
Post-stressed (Number/Rate%)	178/57.83	249/51.19	98/56.57	26/69.16	5/71.43

Morpheme boundaries also did not determine the deletion rates in the post-stressed environment, in which some of the deletion cases occurred at morpheme boundaries. This may be attributable to the number of word types in which deletion occurred at the morpheme boundary. Although 115 word forms had gone through schwa deletion at morpheme boundaries, they were from about 20 word types, most of which are adverbs ending in –ly such as *definitely*. In future studies, carefully designed experiments will be needed to examine the factor in a variety of morphological environments.

4. Discussion

This study set out to investigate grammatical and non-grammatical factors that could affect schwa deletion, which is an optional phonological rule in English. The Buckeye Corpus was used to find schwa-deleted words, since the corpus provides a large data of speech produced in a spontaneous, conversational style. First, it was hypothesized that schwa deletion is qualitatively different in pre-stressed and post-stressed environments. To help resolve the question, factors were investigated with respect to their relative influences on the process depending on stress environment. Results suggest that the phonological factor, more pointedly, the sonority-based onset markedness serves as a constraining factor of schwa deletion only in post-stressed environments. This was partly because a very small number of deletions were found in the pre-stressed environment. One anonymous reviewer pointed out that if pre-stressed schwa deletion is phonetic reduction rather than phonological deletion, some schwa deletions in this position might have not been classified as "deleted". If this is true, it would explain the small number of deletions found in the pre-stress position in this study. Apparently, further research will be required to elucidate different mechanisms underlying pre-tonic and post-tonic schwa deletion.

Furthermore, some words gradually go through vowel loss changes as a result of this deletion process. This sound change diffuses gradually through the lexicon (Bybee 2000), reflecting the differential frequency of schwa deletion between words. For example, Hooper (1976) reported that *every* and *evening* had already become two-syllable words. It seems that the sound change gradually touch more words as schwa-deleted variants are used. Today, words such as *chocolate*, *family*, or *camera* are rarely realized as three-syllable words. The fact that the sound change has exclusively affected post-stressed schwas at least suggests the dominance of post-stress position in this variable phonological process.

Moreover, findings from this study provide new understanding of the phonological factor of schwa deletion. Surprisingly, it was revealed that schwa deletion gives rise to onset clusters of all levels of sonority profile: sonority falls, plateaus, small rises and large rises. This differs from previous studies suggesting that a schwa undergoes deletion when its preceding and following consonants form a sonority rise, in other words, when the Sonority Sequencing Principle is not violated. The fact that such illegal onset clusters are frequently observed even in post-stressed environments leads to the conclusion that the phonetic realization of speech contains a wide range of variability that cannot be explained by traditional phonological theories. In future research, it would be interesting to study acoustic or articulatory characteristics of schwa-deleted word forms and to investigate how the reduced forms are understood in speech processing in the presence of phonetic and semantic contexts.

Interestingly, however, close examination of the phonological distribution of schwa deletion shows that it reflects the universal sonority preferences to some degree: deletion rates were higher in universally preferred onsets, that is, large rises or small rises than in dispreferred onsets, that is, falls. This finding is worthy of attention since it deals with the issue of English speakers' phonological knowledge of the sonority of onset clusters. The significant role of sonority profile in determining deletion rates indicates that schwa deletion is conditioned by the fine-grained universal preferences regarding the sonority of onsets. It is important to note that more deletion occurred in small rises than in falls, both of which are unattested English onsets.

The findings also suggest that English speakers are exposed to dispreferred onset clusters such as falls or plateaus in schwa-deleted word forms in casual speech. Furthermore, the fact that a schwa is more likely to delete when the resulting onset cluster forms a large rise or a small rise, rather than a fall, might conversely indicate that English speakers' knowledge of the universal structure can be explained by the statistical properties of speech input. Put differently, English speakers might learn the sonority-based onset markedness by actually experiencing the bias in phonetic reductions. Certainly, further research will be required to prove this hypothesis, but the findings from this study at least contradict the lack of linguistic evidence for the sonority preferences in English.

However, the effect of lexical frequency was problematic. It could not be accurately evaluated due to limitations of the speech data. To be specific, the frequency of schwa deletion of a word largely depended on the word's frequency in the Buckeye Corpus, thereby obscuring the effects of word frequency on schwa deletion. It was also difficult to explain why more deletion occurred in lower-frequency words than in higher-frequency words according to some of the statistical results, even after controlling for the effects of the Buckeye frequency. Nevertheless, what can be concluded from the results is that any strong positive relationship between word frequency and deletion rates was not found. Eliciting more schwa-deleted word forms will be necessary in future studies to better explain the effect of word frequency on whether or not schwa deletion can occur.

One anonymous reviewer pointed out that it is necessary to examine the semantic context in which the words had undergone schwa deletion. Since the information structure such as givenness and focus determines prosodic prominence of words, contextual properties of a word can also influence its deletion rates. Similarly, previous research has shown that second mentions are temporally reduced relative to first mentions (e.g., Baker and Bradlow 2009). In fact, Patterson et al. (2003) examined the effect of first/second mention on deletion rates as one of discourse variables. However, no such effect was found in either the Switchboard Corpus or the Narrative Corpus. Although the present study was not able to investigate the effect of the sematic/prosodic status, it is nonetheless important to study variable phonological processes in relation to higher-level linguistic information.

As Cole and Hasegawa (2012) suggest, considering the phonetic realization of phonological forms presents not only a challenge, but an opportunity to researchers today. Studying the pattern of phonetic variation can help resolve questions about the phonological system of language, as well as being relevant to uncovering other related aspects of language such as speaking style, regional variation and other linguistic sources of variation.

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