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DEVOICING OF WORD-FINAL /z/ IN ENGLISH

A Comparison of Inflectional and Lexical Instances of /z/

SAITO, Hiroko

1 INTRODUCTION

1.0 The so-called "voiced" obstruents in English are not actually fully voiced unless they appear flanked by voiced sounds. However, even with this in mind, the present writer noticed a significant degree of devoicing of the word-final /z/ phoneme—something that could even be heard as [s] —in actual speech.

1.1 Word-final /z/ includes inflectional endings, and because they are all represented by the letter s, it makes one wonder whether spelling pronunciation was involved. Possible pronunciations of the inflectional endings *-s*, *-'s*, *-es* include [s] after voiceless consonants (e.g. *cats*, *cat's* [kæts]), and it also makes one wonder if this possibility was spreading to other environments as well (e.g. *dogs*, *dog's*).

1.2.1 If one person's speech contains instances of devoiced /z/ as well as comparatively voiced ones, what could be the conditions for devoicing?

1.2.2 Does the native speaker interpret the devoiced fricative as the phoneme /z/, or as /s/? Does she or he ever confuse *knees* with *niece?*

1.2.3 Is there a difference in frequency or degree of devoicing of the final fricative between words like *pleas* and *please;* in other words, does morpheme boundary matter?

1.3 A morpheme boundary affecting the length of preceding segments is not unheard of. It has been reported that in Scottish English, *teas* and *tease* are distinguished by the length of the vowel: /ti: z/ vs. /tiz/.[1] Even in other accents, there is a tendency to lengthen the vowel when speakers want to make the morpheme boundary audible, for example when there is a need to distinguish between *missed* and *mist*—pronounced [mɪs·t] and [mɪst] respectively.[2]

1.4 As for the distinction between *knees* and *niece*, in the speech of London children the /s/ and /z/ opposition is neutralized, especially with inflectional endings, [s] being used for both, "hence *knees* can optionally be homophonous with *niece* [nəis], or *purrs* with *purse* [p ɜ : s]."[3] However, according to Wells, adults do not have this neutralization, and although the /z/ is devoiced, the opposition is maintained because of the length

of the preceding vowel and/or the lenis vs. fortis quality of the consonant.

1.5 This thesis will look at the characteristics of the so-called "voiced" alveolar fricative in English and then report about the experiment carried out in order to investigate whether morpheme boundary affects the pronunciation of the /z/ phoneme. Then the writer will summarise what happened in the past concerning the pronunciation of this sound.

2 PHONETIC DESCRIPTION

2.1.1 Daniel Jones, in his *An Outline of English Phonetics*, explains that when the phoneme /z/ occurs initially or finally, it is generally partially voiceless. He says: "When initial, as the **z** in *zeal* **zi: l**, the sound usually begins without voice and ends with voice; when final, as the **z** in *please* **pli: z**, the sound usually begins with voice and ends without voice." (Section 788. He speaks of / ʒ / also in this same section.) That is, /z/ and / ʒ / in final position are devoiced towards the end of the articulation.

2.1.2 Jones continues on to say that

> When the phoneme is final and preceded by another consonant, a completely voiceless sound is generally used. Thus with most English speakers the **z** of *heads* **hedz** *or sounds* **saundz** (when those words are said by themselves) is completely voiceless and resembles a weak **s**. ....
>
> With some English speakers initial **z** and all final **z** and ʒ, whether preceded by consonants or not, are completely voiceless.[4]

2.1.3 Jones mentions that other voiced fricatives such as /v/ and / ð / are also devoiced in similar positions, but "not to the same degree as z and ʒ."[5]

2.1.4 We can sum up that according to Jones' observation, /z/ tends to be devoiced, by some speakers to a considerable degree, in final position, and especially when preceded by another consonant.

2.2 Gimson follows Jones' description saying that "/v,ð,z, ʒ / tend to be fully voiced only when they occur between voiced sounds.... In initial and (especially) in final positions, the lenis fricatives may be only partially voiced or completely voiceless."[6] By "initial" Gimson means when preceded by silence, and by "final" followed by silence.

2.3 So far the observations have been cited from British authors, but the same descrip-

tion can be found in American text books as well; Kenyon writes,

> When voiced fricatives **v**, ð, **z**, 3, ʤ are final and not followed by voiced sounds, as in **liv**, **smu**ð, **pez**, **ru**3, in ordinary speech the last part of the fricative is whispered, and at the very end is often quite voiceless. .... The same is true to some extent with initial voiced fricatives. When a voiceless sound, or none, precedes, the first part of the fricative is devocalised .... When voiced fricatives are final after a voiced consonant, they are often wholly devocalised .... In very distinct utterance this devocalization of final voiced fricatives is avoided by some speakers.[7]

2.4.1 Even in more recent literature, there is little deviation from these descriptions. Tiffany and Carrell (1987), also an American text book, calls attention to the tendency to devoice /z/, particularly in syllable-final positions. They explain:

> In the final position the tendency is to cut off voicing very shortly after the friction noise begins. Consequently, for much of the duration of the sound the friction may be unaccompanied by voice....[8]

Tiffany's "final position" means phrase final and not word final. That is, "'...his' contains a final [z], but in 'his apple' the [z] is *not* final except in unusual circumstances."[9]

2.5.1 We have seen that the devoicing of /z/ especially in (phrase) final position is a widely recognised phenomenon. In fact, more than a century ago, Henry Sweet (1877) had already pointed out this feature:

> Final (z) may ... be either fully vocalised throughout, or else gradually devocalised, passing from voice to whisper while the consonant position is still being maintained.
>
> Both may be heard (but generally the latter) in 'is,'&c. In final buzzes after other voice consonants the gradual devocalisation is very clearly marked in E[nglish]. Thus in the final buzz in 'bills,' 'adze,' &c., the vocality is of so short duration that the final (z) is almost a purely whispered consonant.[10]

2.5.2 Moreover, Sweet observed that during the articulation of this whispered consonant, "the glottis is not fully opened till the consonant is finished, which therefore consists of voice passing into whisper, followed by a breath-glide."[11] Sweet's observation was before the age of phonetic instruments, but according to Catford (1977), "recent glottographic and laryngoscopic studies show that the English 'voiced' stops and fricatives, even

when not actually voiced, exhibit considerable whisper-like narrowing of the glottis."[12] Catford's assertion is that because of this narrowing of the glottis, English /b,d,v,z/ are potentially voiced even if they actually are not, and are thus distinguished from the purely voiceless /p,t,f,s/ series, and in this respect it is unnecessary to postulate a lenis/ fortis distinction.

2.5.3 Jones (1956) explains that the only difference between the devoiced /z/ (which he transcribes [z̥]) and [s] is that the former is pronounced with "weaker breath force."[13] O'Connor (1973) follows this saying that the difference between /f, θ, s, ʃ/ and /v, ð, z, ʒ/ is on an "energy basis." The sounds in the former group "are always stronger sounds, with more obvious friction," than those of the latter group.[14] O'Connor uses the fortis/ lenis distinction.

2.5.4 This last feature is one of the factors that seem to distinguish devoiced final /z/ from the voiceless fricative [s] (/s/); it is usual to consider the devoiced /z/ as [z̥] and not [s]. Another factor that enables the native speaker to perceive the devoiced /z/ as the /z/ phoneme and not /s/ is the length of the preceding vowel: there would be preclipping for the pure voiceless obstruents, and no clipping of vowels before the so-called voiced obstruents,[15] so the devoiced [z̥], Which is underlyingly [z], is distinguished from [s]. Words like *knees* /ni: z / [ni: z̥] and *niece* /ni:s / [ni· s] are not confused by the native speaker of English.[16]

2.6 Apart from the kind of devoicing mentioned so far, there is, of course, devoicing as a result of assimilation when /z/ is adjacent to a voiceless obstruent: *cause to* [ˈkɔ: z̥ tə].

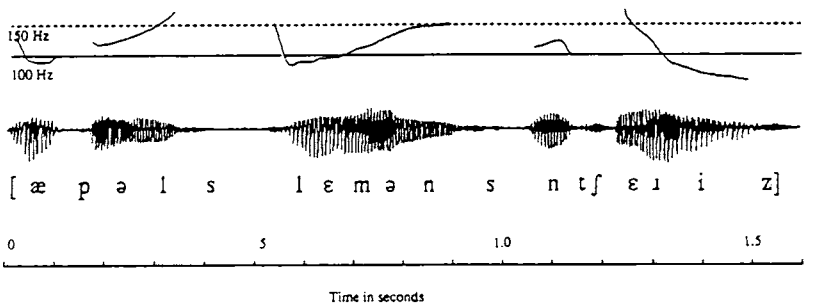

Figure 1

Acoustic records of the phrase "apples, lemons, and cherries." The upper part of the figure shows the fundamental frequency (pitch). The waveform is in the middle, with a narrow phonetic transcription below it. At the bottom is a time scale.[17]

2.7.1 Ladefoged shows us, by means of acoustic records, the devoicing phenomenon. The above diagram is an American English example taken from Ladefoged (1993).

2.7.2 As the explanation accompanying this diagram goes, "the small vertical lines in the waveform correspond to the pulses produced by the vibrating vocal cords," and one can see the difference between a voiced sound (with the pulses visible) and a voiceless sound (without the pulses). Notice that the segments of the waveform corresponding to /z/ of *apples*/ ˈæpəlz/ and *lemons*/ ˈlemənz/ are not pulsed. Ladefoged explains that this shows that "the fricatives at the ends of both 'apples' and 'lemons' are largely voiceless, for there are no vocal cord vibrations visible during these sounds," and he transcribes them as [s].[18] However, the /z/ of *cherries* /ʧ eriz/ is marked [z] by Ladefoged, probably due to the slight pulse visible. This is predictable from what has already been discussed above in 2.1.2 : /z/ is more liable to be devoiced when preceded by another consonant, as in *apples*, *lemons*, than when it is not.

2.8.1 We have seen from past and present literature that the devoicing of the voiced alveolar fricative [z] is a common phenomenon in both British and American English, and that phoneticians, though they use different terms ("devoicing," "devocalising," etc.) to describe it and have not necessarily agreed on what is actually happening during the process (some say it is the different amount of energy put in, others say that the state of the glottis is different), all have recognised the phenomenon itself and there is general agreement as to the fact that the devoiced variety is perceived as a different phoneme from the purely voiceless variety.

2.8.2 We also know that the degree of devoicing of /z/ (and /ʒ/) is greater than the other voiced fricatives, but that there is variation among speakers and accents.

3 The Experiment

3.0 At the outset of this thesis, the writer posed a question of whether there were differences in the degree or frequency of devoicing between inflectional /z/ and lexical /z/, and this question is yet to be answered. In this chapter, we will look at an experiment conducted among a small group of British English speakers.

Aim

3.1 The aim of the experiment is to find out whether there are any differences in the degree of devoicing between the pronunciation of inflectional /z/ and lexical /z/—to see whether speakers differentiate in their minds between the two environments: one with and the other without a preceding morpheme boundary.

Procedure

3.2.1 Fifteen pairs of homophones containing final /z/ were collected. One of the pair has an inflectional /z/—that is, the /z/ sound represents either the third person singular (-s), the plural form ending, or the possessive ('s) pronunciation—and the other of the pair has a lexical /z/ —that is, the /z/ is an inseparable part or that word.

3.2.2 Here is the list of homophonous pairs chosen:

1. /reiz/ rays vs. raise
2. /meiz/ May's vs. maze
3. /greiz/ Gray's vs. graze
4. /feiz/ Fay's vs. phase
5. /saiz/ sighs vs. size
6. /waiz/ Y's vs. wise
7. /gaiz/ guys vs. guise
8. /rouz/ rows vs. rose
9. /pli:z/ pleas vs. please
10. /lu:z/ Lou's vs. lose
11. /bu:z/ boos vs. booze
12. /kɔ:z/ cores vs. cause
13. /pɔ:z/ pores vs. pause
14. /lenz/ Len's vs. lens
15. /bronz/ Bron's vs. bronze

3.3.1 For each of these pairs, short sentences were constructed making sure that the homophonous words in the pair appeared in the same environment. The sentences themselves were made to be homophonous.

e.g. They went to *Gray's*.

They went to *graze*.

3.3.2 In some cases short phrases were used instead of full sentences.

3.4 In one pair, the test words were placed at the end of the sentences / phrases so as to make the /z/ come before a pause, the position where devoicing is very likely to occur. The same test words were used again, this time so that they would appear directly before a word beginning with a voiceless obstruent: that is, the final /z/ of the test words, having been placed directly before a voiceless obstruent, would undergo anticipatory assimilation and become devoiced. Thus, we have four sentences or phrases in each set with the test words appearing in the positions that the greatest degree of devoicing is predicted to occur.

e.g. They went to*Gray's*.	inflectional /z/ + pause
They went to *graze*.	lexical /z/ + pause
Gray's cattle	inflectional /z/ + voiceless obstruent
Graze cattle	lexical /z/ + voiceless obstruent

3.5 The full list of all 60 sentences used in the experiment can be found in Appendix A.

3.6.1 Each sentence or phrase was written on a separate card, without any marking on the test words. The cards were shuffled well so that the homophonous sentences or phrases did not appear consecutively. There were four sentences or phrases for each of the fifteen sets of test words, which means a total of sixty cards. These cards were numbered from 1 to 60.

3.6.2 The subjects were asked to read all sixty cards, first the number, then the sentence or phrase on the card. They were not informed of the object of the experiment, and were asked to read at normal speed and with natural intonation.

3.6.3 The readings were recorded in the recording room at Wolfson House, University College London, on a DAT recorder, using a microphone. The subjects had the nodes of the laryngograph strapped in place on the neck to monitor the vibrations of the vocal folds. The speech waveform and the larynx waveform (vocal fold vibrations) were recorded on separate tracks of the DAT tape. The recordings were made between April and June, 1993.

3.6.4 Recordings were made by five subjects, of which two were females and three males.[19] They were all native speakers of British English with RP and other accents:

Subject A: Female, age early 30's, RP accent

B: Female, age mid 40's RP accent

C: Male, age early 40's, RP accent

D: Male, age late 20's, London accent

E: Male, age 20's, Hampshire accent

3.7 These recordings were then analysed on the computer using the KAY PCLX program.

Measurements

3.8.1 Figure 2 is (a) speech waveform and (b) larynx waveform for the pronunciation of /pli:z/ in "The 'please' couldn't have been in earnest" by a male speaker. Figure 3 is an enlarged waveform display of the last part of the vowel /i:/ and all of /z/. We can see in figure 3(a) the periodic waveform of the vowel changing to the aperiodic, scratchy line of the fricative /z/. Looked at closely, the beginning part of /z/ is scratchy but there is a hump of periodicity. This indicates that the fricative is voiced. Then, it loses its regularity altogether just before 70 ms and the scratchy line continues. This is the waveform for a devoiced fricative. The vocal fold vibration waveform in (b) corresponds to this.

3.8.2 Measurements were made, of recorded sentences and phrases for each subject, by

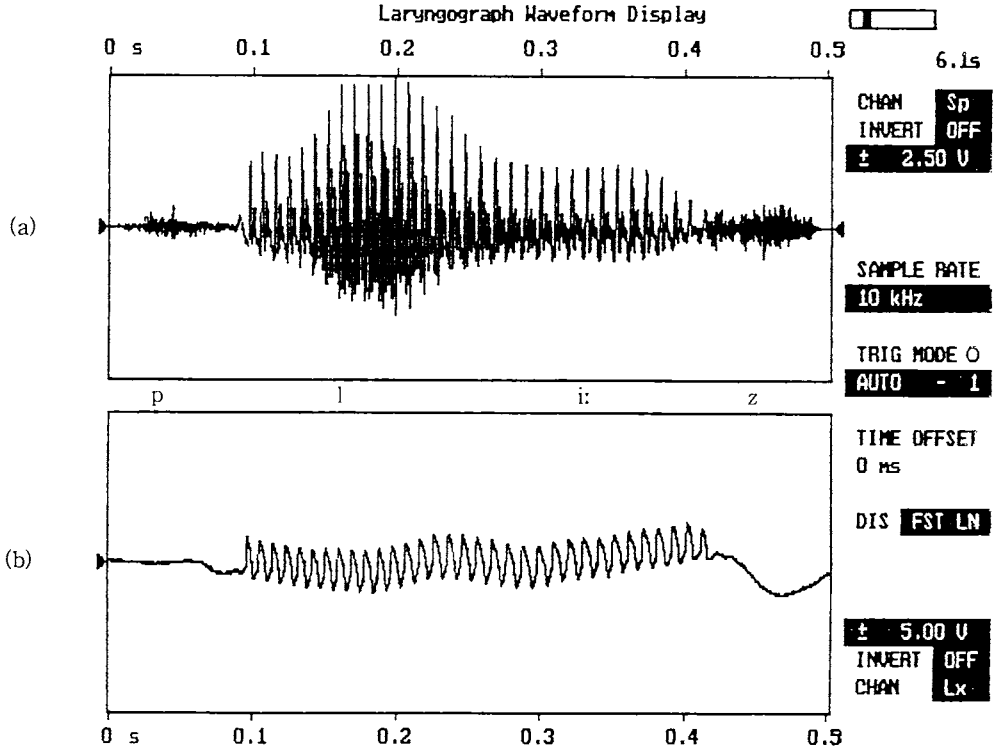

Figure 2 Speech waveform and Larynx waveform for /pli:z/ by Speaker E

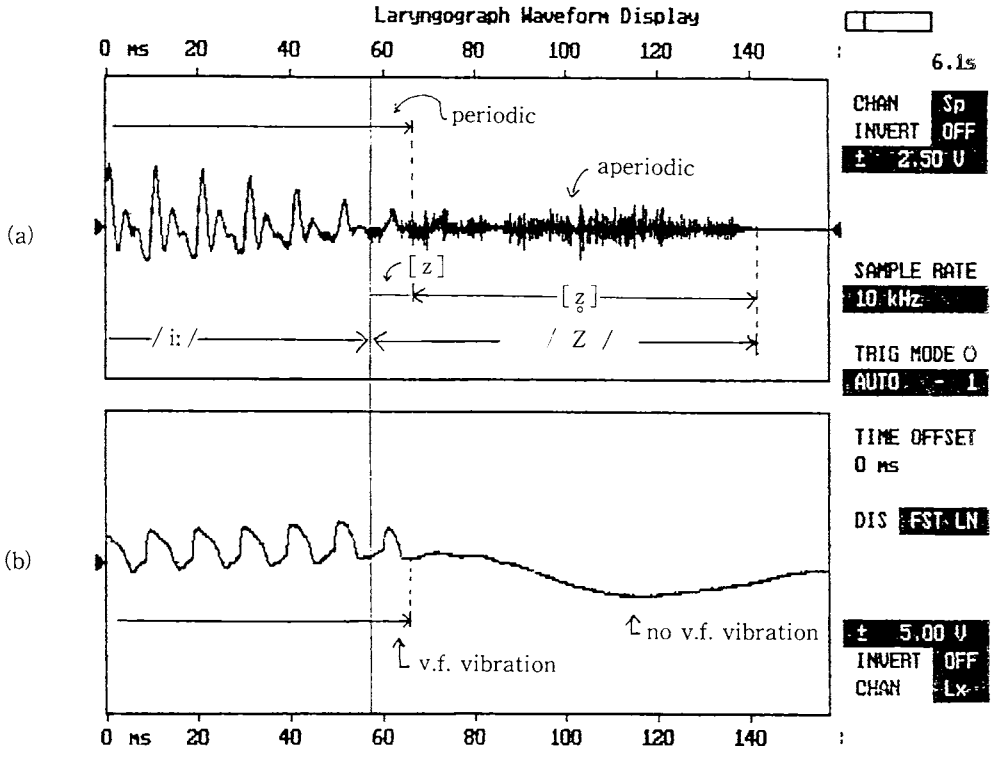

Figure 3 Enlarged waveform of last part of/i:/ and all of/z/of/pli:z/for Speaker E

moving the cursors on the computer screen displaying such waveforms.

3.8.3 Duration of (1) segments before the fricative (/l/, /r/ were difficult to separate off from the vowel and had to be measured together), (2) the fricative /z/, and (3) voicing were measured for inflectional /z/ and lexical /z/ before a pause and before a voiceless consonant. The results have been tabulated in Appendix B.

Observations

3.9.1 When looked at pair by pair, there were instances which showed interesting differences in waveform between inflectional and lexical /z/'s, but the results did not show any consistent pattern: there were examples where duration of inflectional /z/ was noticeably longer than lexical /z/, and there were instances where the duration of the inflectional /z/ was shorter than the lexical /z/, while sometimes both showed identical waveform.

3.9.2 Duration of devoicing of /z/ was also erratic. On the whole, the only pairs that

showed any significant correlation after running the t-test[20] were the duration of /z/ and its voicing between inflectional /z/ and lexical /z/ before a voiceless consonant for subject A (female) and the duration of segments before the /z/ in pre-consonantal position for speaker D (male).

3.9.3 This result does not contribute much to our search for any significant differences in devoicing between inflectional /z/ and lexical /z/. One of the differences that did show up in the tabulations is that the average duration of devoicing is greater before a voiceless consonant than before a pause (for speakers A, C, D. The average was about the same for speaker B, and the devoicing was longer for pre-pausal position than before a consonant for speaker E).

3.9.4 The other noticeable difference is that for the two female speakers, the average duration of voicing of /z/ was always in the negative (that is, devoicing began before the /z/). There seems to be a general tendency for young British female speakers to devoice completely all obstruents in final position[21] and this may be the factor behind our results. Previous writers have noted that amount of devoicing differed among individuals, and gender difference may be one possibility, at least in present-day British English. However, the number of subjects in our experiment is too small to speak of a general tendency among female speakers.

Conclusion

3.10 The object of this experiment was to find out whether there were any differences, especially in respect to the amount of devoicing between inflectional and lexical /z/'s. Our measurements did not reveal any consistent, significant differences, but there were some signs of differences that may be worth further investigtation.

3.11 The present experiment placed its emphasis on the comparison of inflectional and lexical /z/'s in homophonous pairs of words but did not delve into the differences of duration among the different vowels[22] before the /z/ and the influence they might have on the duration of the fricative, but as far as we can see from our data, there does not seem to be any correlation.

3.12 The point made by Jones and Sweet about the greater degree of devoicing after an obstruent (as in /lenz/, /bronz/) compared to after a vowel was not consistent in our results.

4 HISTORICAL NOTE

4.1 Attention should be brought to one phenomenon in the history of English: that which Jespersen calls "numerical metanalysis."[23] Numerical metanalysis is a kind of metanalysis "affecting the numerical value of a form. A form that is originally a singular, may be taken to be plural, or vice versa. This is especially frequent where the *s*-ending is involved...."[24]

4.2.1 There are two kinds of numerical metanalysis: one is where a lexical *s* is taken to be the plural ending, and the word, even though it was originally singular, is treated syntactically as plural and sometimes a new singular form without the *s* is even created. Examples where originally singular forms are now treated as plural because of the *s* -ending are: *alms* (from old English ælmesse), *eaves* (< OE efes), *riches* (< Middle English richesse), etc.; and where a new singular form has been created by back-formation: *pea* (from ME pese), *cherry* (< ME cherris), *sherry* (< Spanish sherris), *riddle* (< ME redeles), *burial* (< ME buryels), *asset* (< ME assets), *sash* (< French châssis), *caterpillar* (< Old French chateplose), etc.[25]

4.2.2 The other kind is where an inflectional *s*-ending has been taken to be an inseparable part of the word and thus that word, which was originally the plural form, is treated as a singular noun: e.g. *invoice* (from invoyes = plural form of invoy), *truce* (< ME trewes = pl. of trewe), *bodice* (< bodies), *dice* (< dies); *measles*, *smallpox* (< small pocks); *bellows*, *gallows*, *news*, *scissors*, *barracks*, etc.[26]

4.3.1 During the 15th and 16th centuries, there was a sound change where voiceless fricatives [f, θ, s] underwent voicing and became voiced [v, ð, z] after a weakly stressed vowel.[27] By this rule, *-es* endings of the genitive singular and the plural of nouns such as ME sones /sunes/ (=son's, sons, sons'), and the third person of verbs such as ME comes /kumes/ came to be pronounced /sunez/ and /kumez/ respectively (because of the weak *e*).[28] For words like ME richesse, there was a stress shift onto the first syllable when it came into English from French, and this created the condition for the [s] to [z] sound change. As soon as this change took place, the [z] was taken to be the plural ending.[29] Most of the examples cited in 4.2.1 above can be explained in the same way.

4.3.2 A more recent example of the plural interpretation of an originally singular noun is the word *kudos*. This word came into English from Greek in the 19th century. It started as an uncountable noun pronounced ['kju:dɒs] with a voiceless [s] at the end. (The

word has this voiceless sound in Greek.) This is the form given in dictionaries for British pronunciation, but in American English, the pronunciation [ˈku:douz] is common, interpreting the final *s* as the plural ending. The Americans now even have a singular form *kudo*.

4.4 [s] was not changed to [z] after a strong syllable as in *invoice* (Fr. enˈvoys), or *dice*, and the fricative was pronounced with a voiceless [s] for these words, rather than with the [z] of the plural ending pronunciation rule. This voiceless [s] sounds as if it is an inseparable part of the word, a lexical [s], and this is said to be the reason why these words, along with *truce* and *bodice*, came to be felt as the singular form.[30] *Bellows* and *gallows* had a vulgar pronunciation [ˈbeləs] and [ˈgæləs] existing beside the educated [ˈbelouz] and [ˈgælouz], and this vulgar [s] made these words sound singular.[31]

4.5 We have briefly looked over Jespersen's "numerical metanalysis" and how presence or absence of voicing of the word-final alveolar fricative has influenced the numerical status of that word: since the rule for inflectional *s* pronunciation is voicing, a voiced [z] at the end of a word is interpreted as an inflectional ending, whereas a voiceless [s] is interpreted as an inseparable part of that word. Naturally, a well established word such as *please* [pli:z] would no longer be analysed as a plural form of *plea, but as we have seen, comparatively new words used infrequently (like *kudos*) still has a chance of undergoing metanalysis.

5 CONCLUSION

5.1 We saw in Section 2 from the descriptions of the pronunciation of the /z/ phoneme that in the phrase final position (i.e. before a pause), it tends to be devoiced to a considerable degree. However, we also saw that this devoiced sound is differentiated from the /s/ phoneme by the native speaker, hence the necessity to keep the /z/ phoneme in this position and consider the devoiced version as [z̥] and not /s/ [s].

5.2 We found from historical evidence that the inflectional /z/ and lexical /z/ were not always distinctly kept apart. Interpretation of which category an *s*-ending belonged to depended at times on how it was pronounced: whether it was voiced or not. Although we do not know whether the 16th century "voiced" /z/ accompanied full vocal fold vibration, or whether it was devoiced considerably like today's final /z/ with the state of the glottis being the distinctive factor, we do know that it was something that could be considered as

a separate phoneme from an unvoiced /s/, because the interpretation of the sound (is it inflectional, or lexical?) depended on the different pronunciations.

5.3 In present-day English, however, whether a /z/ is inflectional or lexical has been mostly settled, and /z/ can be found both as an inflectional ending and as an inseparable part of a word. Moreover, from the experiment in Section 3, we saw that there were no significant differences to be found in the degree of devoicing, the duration of the friction, nor in the duration of the preceding vowels to hint that the speaker was differentiating between an inflectional /z/ and a lexical /z/.

5.4 But we also saw that in Scottish English, morpheme boundary does affect the length of the vowel before /z/, and that in the speech of London children, the /s/ and /z/ opposition was neutralised. From these facts, it might be said that there is always a possibility that further devoicing of /z/ in final position could bring about a reorganization of the distribution of /z/ and /s/.

5.5 The results of the experiment did not produce a consistent correlation of factors concerning the devoicing of inflectional and lexical /z/'s, and it must therefore be concluded at this stage that there is no distinction in the amount of devoicing between the two categories in present-day British English. Other conditions, such as style (speed of utterance, intonation) and sound environment (what sounds /z/ is adjacent to) etc. were not investigated in this study, and our analysis had to be based on recordings of short, artificial sentences, mainly because of the difficulty in collecting natural utterances that include a significant number of instances of inflectional and lexical /z/ by one speaker.

5.6 Further studies must be made in order to see if there is any specific environment that conditions devoicing within the speech of one speaker. Gender difference is another possible factor to be investigated.

[This paper is a slightly modified version of my dissertation submitted to the Phonetics Department, University College London, in partial fulfilment of the MA degree in 1993.]

Notes

1 O'Connor (1973), p. 255; McClure (1977), p. 15.
2 Mentioned in a lecture at University College London in 1993 by John Wells.
3 Wells (1982), Vol. 2, p. 330.

4 *Outline*, sections 789 and 790.
5 Ibid. section 794.
6 *An Introduction to the Pronunciation of English*, 4th ed. p. 180.
7 Kenyon (1950), section 43.
8 p. 316.
9 Ibid. p. 316
10 p. 80 section 233.
11 Ibid. section 234
12 p. 112.
13 Section 339.
14 O'Connor (1973) p. 140.
15 Denes (1955).
16 However, see 1.4 for exceptions.
17 From *A Course in Phonetics*, Third Edition, p. 185 figure 8.2.
18 Ibid. p. 186,
19 The writer is grateful to the five speakers, who willingly gave a part of their time to co-operate in the experiment.
20 The t-score for pairs of 15 items is 2.131 at 5 per cent significance level.
21 This fact was pointed out to the writer by Valerie Hazan of UCL.
22 As in McClure (1977).
23 *A Modern English Grammar* Vol. II, section 5.61ff.
24 Ibid. 5.61.
25 Ibid. 5.62, 5.631.
26 Ibid. 5.711, 5.712.
27 The same as Verner's Law in Primitive Germanic. *MEG*, Vol. I, 6.511.
28 *MEG*, Vol. I, 6.61.
29 *MEG*, Vol. II, 5.62.
30 Ibid. 5.711.
31 Ibid. 5.712.

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APPENDIX A

This is the list of sentences and phrases that were used in the experiment. There are fifteen sets. Each set consists of sentences or phrases that contain a word with (a) inflectional /z/ followed by a pause, (b) lexical /z/ followed by a pause, (c) inflectional /z/ followed by a voiceless consonant, (d) lexical /z/ followed by a voiceless consonant, in that order.

1. /reiz/
   The sun's rays
   The son's raise
   The sun's rays could have made him feel better.
   The son's raise could have made him feel better.
2. /meiz/
   That's not May's!
   That's not maze!
   May's can be exported.
   Maze can be exported.
3. /greiz/
   They went to Gray's.
   They went to graze.
   Gray's cattle
   Graze cattle
4. /feiz/
   That's Fay's.
   That's phase.
   Fay's has no importance.
   Phase has no importance.
5. /saiz/
   Big sighs
   Big size
   Sighs could be crucial.
   Size could be crucial.
6. /waiz/
   Your Y's.
   You're wise.
   The Y's tend to stand out.
   The wise tend to stand out.
7. /gaiz/
   I don't like the guys.
   I don't like the guise.
   His guys can fool you.
   His guise can fool you.
8. /rouz/
   She straightened the rows.
   She straightened the rose.
   The rows could have been crooked.
   The rose could have been crooked.

9. /pli:z/
   They heard her pleas.
   They heard her 'please.'
   The pleas couldn't have been in earnest.
   The 'please' couldn't have been in earnest.
10. /lu:z/
   She's going to Lou's.
   She's going to lose.
   Lou's three books
   Lose three books
11. /bu:z/
   Are you ready for the boos?
   Are you ready for the booze?
   Boos can make you feel depressed.
   Booze can make you feel depressed.
12. /kɔ:z/
   She searched for the cores.
   She searched for the cause.
   The cores can be hidden.
   The cause can be hidden.
13. /pɔ:z/
   It could've been the paws.
   It could've been the pause.
   The paws can destroy the whole thing.
   The pause can destroy the whole thing.
14. /lenz/
   That's my Len's!
   That's my lens!
   Len's cap
   Lens cap
15. /bronz/
   That's Bron's.
   That's bronze.
   Bron's can be eliminated.
   Bronze can be eliminated.

APPENDIX B

Table 1 Measured Duration (ms) of Segments for Speaker A

	inf z pause			lex z pause			inf z cons			lex z cons		
reiz	548.3	176.1	24.8	566.8	200.8	0	316.5	47.6	-13.7	332.6	57.6	-16.1
meiz	472.5	192.9	0	532.1	155.0	24.7	367.8	50.0	-15.8	326.9	65.5	-18.2
greiz	537.6	206.5	-5.4	477.8	234.0	16.8	342.6	74.2	-11.6	336.5	64.8	-13.6
feiz	467.3	233.6	13.5	418.9	207.7	12.6	286.1	19.0	-24.0	390.9	35.2	-4.2
saiz	420.8	201.2	7.8	490.5	226.2	11.0	269.2	34.9	-19.4	273.9	50.5	-12.5
waiz	607.0	155.6	0	523.7	189.0	15.9	387.0	39.3	-15.0	353.9	48.1	-13.1
gaiz	505.4	170.2	-11.9	529.4	188.6	0	381.2	50.7	-9.4	362.5	77.7	-8.0
rouz	556.4	209.8	16.0	527.6	199.5	-18.8	289.3	68.0	-27.7	384.4	68.1	-15.1
pli:z	450.9	177.5	7.7	423.8	167.7	10.5	250.4	46.5	-29.2	412.7	107.6	-14.5
lu:z	506.8	215.9	0	493.8	178.2	-13.6	320.0	51.7	-51.0	306.0	140.0	-27.3
bu:z	415.9	129.3	-44.2	509.0	199.0	11.4	248.5	62.3	-9.8	233.6	47.8	-19.2
ko:z	456.3	160.6	0	409.8	182.8	0	247.7	40.8	-22.5	316.3	47.0	-14.0
po:z	440.4	173.4	0	464.8	142.2	-27.2	248.4	52.8	-12.9	303.1	70.7	-6.7
lenz	565.1	140.4	-26.7	619.2	187.7	0	378.8	49.1	-27.7	369.3	69.1	-25.8
bronz	547.2	185.5	0	517.5	135.0	7.9	421.0	60.1	-16.5	356.2	48.1	-20.2
AVERAGE	499.9	181.9		500.3	186.2		317.0	49.8		337.3	66.5	
duration (ms)			-1.2			3.41			-20.4			-15.2
	(a)	(b)	(c)	(a')	(b')	(c')	(d)	(e)	(f)	(d')	(e')	(f')

T-Score e 2.4
f 2.2

Note:

(a), (a'), (d), (d') : duration of segments before /z/, excluding obstruent

(b), (b'), (e), (e') : duration of friction

(c), (c'), (f), (f') : duration of vocal fold vibration corresponding to friction (negative measurement means v. f. vibration had stopped before friction began)

Table 2 Measured Duration (ms) of Segments for Speaker B

	inf z pause			lex z pause			inf z cons			lex z cons		
reiz	530.0	168.7	-23.9	511.6	183.9	-33.1	399.7	80.2	-5.3	335.3	76.9	-16.7
meiz	386.4	186.9	-21.7	417.9	202.1	-9.6	346.9	64.9	-14.8	217.6	63.9	-13.5
greiz	550.9	239.7	0	486.8	244.8	-14.6	324.6	67.0	-17.0	330.0	75.2	-12.0
feiz	409.7	181.1	-22.1	377.5	184.6	-12.3	351.8	150.0	-9.8	261.2	101.2	-12.0
saiz	426.1	225.7	-7.4	399.0	223.1	-10.0	360.2	93.4	-8.2	313.5	61.7	-12.6
waiz	448.6	155.0	-10.8	497.4	202.5	-22.0	398.0	88.9	-13.8	379.0	93.3	-7.5
gaiz	330.4	156.2	-17.9	414.4	215.9	0	266.3	69.8	-13.7	282.7	78.4	-7.9
rouz	451.7	254.9	8.5	463.5	179.9	-12.5	296.3	94.4	-8.6	388.8	89.1	-10.4
pli:z	361.9	174.1	0	426.3	186.5	-21.3	298.2	73.4	-11.9	418.5	146.7	-25.2
lu:z	474.9	204.9	0	512.6	161.1	-10.3	309.4	97.1	-10.4	333.1	135.9	-8.8
bu:z	398.2	186.0	-6.0	322.2	209.9	-2.1	314.2	94.7	-5.7	331.2	97.0	-6.0
ko:z	365.5	201.2	-15.8	334.8	202.2	0	259.5	98.9	-7.2	283.1	93.4	-8.9
po:z	363.9	215.6	-16.2	329.4	166.6	-11.6	340.6	74.4	-6.6	303.8	79.8	-8.4
lenz	470.6	184.7	0	421.6	224.0	-12.9	386.8	93.3	-8.8	273.0	93.5	-12.4
bronz	503.6	202.3	-10.3	554.2	219.8	-6.3	429.3	114.8	-10.0	426.9	82.4	-9.0
AVERAGE duration (ms)	431.5	195.8	-9.6	431.3	200.5	-11.9	338.8	90.3	-10.1	325.2	91.2	-11.4
	(a)	(b)	(c)	(a')	(b')	(c')	(d)	(e)	(f)	(d')	(e')	(f')

Note:

(a), (a'), (d), (d') : duration of segments before /z/, excluding obstruent

(b), (b'), (e), (e') : duration of friction

(c), (c'), (f), (f') : duration of vocal fold vibration corresponding to friction (negative measurement means v. f. vibration had stopped before friction began)

Table 3 Measured Duration (ms) of Segments for Speaker C

	inf z pause			lex z pause			inf z cons			lex z cons		
reiz	434.5	138.8	13.3	352.0	131.8	0	347.9	60.0	0	296.5	72.8	10.2
meiz	310.3	159.7	-16.5	293.2	187.8	-16.5	308.3	85.5	0	327.8	74.4	0
greiz	350.9	197.9	23.0	351.6	150.5	33.0	243.0	51.2	15.2	270.3	61.4	0
feiz	343.2	159.8	34.5	338.6	155.5	19.2	290.1	112.0	10.6	358.7	106.3	-4.7
saiz	376.6	152.7	0	356.2	139.2	21.2	328.6	66.2	0	303.5	48.5	-10.1
waiz	490.9	146.2	9.1	457.2	154.4	0	366.9	103.3	-8.4	389.3	62.9	8.3
gaiz	321.1	156.3	0	377.1	181.7	18.2	317.8	46.3	0	346.7	58.3	0
rouz	354.9	172.6	0	335.7	160.4	5.0	380.9	115.4	23.9	391.5	67.4	0
pli:z	329.0	130.5	0	319.6	143.2	10.2	256.4	96.3	7.6	314.2	145.1	0
lu:z	380.4	173.9	19.3	369.8	152.5	13.6	286.4	114.4	-11.9	259.0	100.8	9.7
bu:z	321.5	129.5	-4.6	310.5	120.5	0	334.6	79.5	5.9	292.9	68.4	0
ko:z	302.0	165.4	20.4	295.8	152.8	8	286.5	67.4	0	283.3	56.5	8.3
po:z	319.1	169.4	19.7	331.9	133.9	0	260.2	65.4	5.8	300.8	90.0	13.1
lenz	436.9	130.4	0	356.7	137.1	26.6	417.3	33.0	-29.1	317.4	62.4	0
bronz	417.7	158.7	0	397.4	153.4	19.0	351.0	57.8	7.3	340.8	68.0	11.5
AVERAGE duration (ms)	365.9	156.12	7.9	349.6	150.3	10.5	318.4	76.9	1.8	319.5	76.2	3.1
	(a)	(b)	(c)	(a')	(b')	(c')	(d)	(e)	(f)	(d')	(e')	(f')

Note:

(a), (a'), (d), (d') : duration of segments before /z/, excluding obstruent

(b), (b'), (e), (e') : duration of friction

(c), (c'), (f), (f') : duration of vocal fold vibration corresponding to friction (negative measurement means v. f. vibration had stopped before friction began)

Table 4 Measured Duration (ms) of Segments for Speaker D

	inf z pause			lex z pause			inf z cons			lex z cons		
reiz	386.7	157.5	23.5	391.5	205.2	14.2	299.3	38.3	11.4	264.8	58.3	13.4
meiz	376.3	159.6	56.1	351.3	243.3	48.7	274.1	78.1	26.5	200.9	61.9	12.0
greiz	363.9	178.5	14.7	387.3	198.8	15.0	361.7	101.7	17.3	266.1	70.8	18.6
feiz	305.3	185.7	44.7	324.8	162.4	26.9	279.2	164.9	16.0	212.8	80.9	12.3
saiz	382.9	174.7	22.4	338.6	191.2	23.5	285.9	59.3	13.0	206.9	56.0	5.5
waiz	465.5	194.4	10.6	481.0	199.3	46.5	412.5	126.7	19.1	369.5	90.1	16.4
gaiz	410.6	172.7	27.8	392.7	144.9	23.6	248.2	51.9	10.9	289.0	53.8	14.7
rouz	401.7	187.3	17.7	393.2	174.5	20.4	361.3	60.6	9.3	340.2	66.6	17.3
pli:z	328.2	153.8	24.6	332.9	206.8	0	230.0	76.0	14.7	280.6	91.7	22.4
lu:z	436.0	186.5	0	422.1	161.2	17.4	403.8	228.2	12.8	328.3	161.6	9.0
bu:z	350.1	204.2	0	330.0	212.9	17.0	247.1	62.4	9.8	228.4	57.7	14.9
ko:z	310.3	184.8	29.2	292.3	177.3	30.6	249.8	63.5	16.2	255.9	72.7	14.5
po:z	335.4	205.2	12.1	328.0	202.7	15.9	263.7	64.3	6.6	201.7	48.6	12.9
lenz	373.1	198.4	18.0	435.3	138.5	11.7	345.0	78.9	12.4	341.9	70.3	9.8
bronz	419.0	148.6	25.7	425.7	186.5	8.4	365.7	80.5	20.5	284.4	75.0	8.1
AVERAGE	376.3	179.46		375.1	187.0		308.5	89.0		271.4	74.4	
duration (ms)			21.8			21.32			14.4			13.5
	(a)	(b)	(c)	(a')	(b')	(c')	(d)	(e)	(f)	(d')	(e')	(f')

T-Score 3.2

Note:

(a), (a'), (d), (d') : duration of segments before /z/, excluding obstruent

(b), (b'), (e), (e') : duration of friction

(c), (c'), (f), (f') : duration of vocal fold vibration corresponding to friction (negative measurement means v. f. vibration had stopped before friction began)

Table E Measured Duration (ms) of Segments for Speaker E

	inf z pause			lex z pause			inf z cons			lex z cons		
reiz	433.2	121.4	31.7	483.1	102.7	10.9	262.5	48.6	9.1	278.8	49.8	11.6
meiz	346.1	79.8	0	361.5	106.3	0	242.8	50.3	14.5	214.2	37.6	11.5
greiz	453.5	75.6	-5.3	392.7	96.1	0	371.8	73.3	17.7	350.7	59.8	10.8
feiz	360.6	82.9	0	353.4	98.1	0	335.4	87.5	0	276.0	61.7	3.3
saiz	325.8	91.1	35.3	348.6	113.0	28.7	297.6	50.8	9.2	249.6	54.4	12.5
waiz	442.5	91.4	15.8	402.5	92.7	11.4	415.2	272.2	35.7	384.1	66.8	20.5
gaiz	334.3	94.9	25.3	383.6	85.0	17.0	264.2	48.7	13.5	281.2	41.8	10.6
rouz	428.1	118.6	15.0	391.5	118.8	19.2	357.5	62.5	23.7	362.7	35.1	16.3
pli:z	428.5	99.7	0	380.5	95.4	13.6	200.7	67.1	16.2	313.6	83.0	15.1
lu:z	511.3	72.9	0				379.9	134.9	18.7			
bu:z	310.6	110.3	14.3	292.8	131.1	0	225.7	55.3	5.6	230.3	49.9	9.0
ko:z	320.5	113.7	20.0	295.9	107.8	16.2	227.7	56.4	7.3	237.7	53.6	8.4
po:z	295.0	114.0	0	295.4	117.6	22.9	211.7	54.6	9.9	234.2	52.7	12.9
lenz	376.0	44.4	20.1	432.3	87.5	0	417.5	49.9	16.0	348.2	58.3	0
bronz	382.2	92.9	0	397.0	127.7	23.6	286.9	49.3	7.5	317.7	65.0	10.5
AVERAGE duration (ms)	383.2	93.57	11.5	372.2	105.7	11.6	299.8	77.4	13.6	291.4	54.9	10.9
	(a)	(b)	(c)	(a')	(b')	(c')	(d)	(e)	(f)	(d')	(e')	(f')

Note:

(a), (a'), (d), (d') : duration of segments before /z/, excluding obstruent

(b), (b'), (e), (e') : duration of friction

(c), (c'), (f), (f') : duration of vocal fold vibration corresponding to friction (negative measurement means v. f. vibration had stopped before friction began)

* For this speaker measurements for lexical /lu:z/ are missing due to mispronunciation. The average has been calculated excluding these gaps in the column.

英語の「有声」の妨げ音は，有声音に挟まれていないと実際は完全に有声にはならない。しかし，その中でも語末の/z/は，時として[s]に聞こえるほど著しく無声化する。語末の/z/は，元々その語から切り放すことのできない一部である語彙的な場合（例：please）と，複数や所有を表す語形変化語尾-s，-'s，-esが有声音の後にきたときの発音の場合（例：pleas）とに分けられる。後者の場合は綴り字がsであり，無声音の後では規則的に[s]と発音されるわけだが，この発音の綴り字が有声であるはずの/z/の無声化に影響を与えているということはないのだろうか。もしあるとすれば，語彙的な/z/と語形変化語尾の/z/には，無声化の度合いなどに違いは無いのだろうか，という疑問を出発点に，英語のネイティヴスピーカーの発音を録音し，声帯の振動を分析する実験を行った。

実験の結果には，ポーズの前の/z/の方が無声子音の前の/z/より無声化の度合いが少ないことや，男性に比べて女性の方が全体的に無声化が著しいなどの傾向は見られたものの，語彙的な/z/と語形変化語尾の/z/との間には発音上，統計的に有意差があると言えるはっきりとした違いは出なかった。

現代英語では/z/が語彙的なものか語形変化語尾なのかは知識として話者の頭の中に定着しており，無声化してもそれはあくまで/z/の音素に属する音が「無声化」したのであって元々無声の/s/の音素に属する音と混同されることはほとんどない。しかし，方言によってはこの限りでないこともあり，また数異分析の例に見られるように，過去においては語彙的な-sと語形変化語尾の-sを区別する手段としてその部分の発音が無声か有声かが指標であった時期も存在したので，語彙的な/z/と語形変化語尾の/z/とが将来発音上区別される可能性は皆無とは言えないのである。