

STOP EPENTHESIS AT SYLLABLE BOUNDARIES

Natasha Warner

Department of Linguistics
University of Arizona, Tucson, Arizona, and
Max Planck Institute for Psycholinguistics, Nijmegen, the Netherlands
nwarner@u.arizona.edu

Andrea Weber

Department of Speech and Hearing
City University of New York, New York, and
Max Planck Institute for Psycholinguistics, Nijmegen, the Netherlands
andweb2@yahoo.com

ABSTRACT

This paper investigates the production and perception of epenthetic stops at syllable boundaries in Dutch and compares the experimental data with lexical statistics for Dutch and English. This extends past work on epenthesis in coda position [1]. The current work is particularly informative regarding the question of phonotactic constraints' influence on parsing of speech variability.

1. INTRODUCTION

In many languages, speakers variably produce epenthetic stops between nasals and following obstruents, as for example the optional [k] in “young[k]ster” in English or “ang[k]stig” ‘anxious’ in Dutch. This occurs when the velum closes for the following obstruent before the oral closure for the nasal is released, creating a time period with complete closure of the vocal tract (a stop). This paper focuses on epenthetic stops in clusters which are split across a syllable boundary (medial to the word), as in “ang[k]stig,” rather than those which occur in the coda of a syllable (often word-finally), such as “zing[k]t” ‘sings.’ Thus, this work complements past research [1] on word-final epenthesis. As in the previous work, this paper investigates primarily epenthesis in Dutch.

The main topic of this study is perceptual: under what circumstances do listeners perceive an epenthetic stop as a real stop? Because of the optionality of epenthesis, we investigate production as well. We also examine lexical statistics on the number of words containing the relevant clusters in order to determine how often listeners might hear epenthesis.

2. METHODS

2.1. Production

For each of the medial consonant clusters in Table 1 (the cluster consisting of the nasal on the left followed by the obstruent on the top), 14 non-word items composed of Dutch phonemes were

created. An example item for each cluster appears in the table. Except when the nasal and the following obstruent have the same place of articulation and the obstruent is a stop, these clusters provide an environment in which speakers may produce an epenthetic stop, as shown below each example.

Two native Dutch speakers produced all items (one speaker once and the other twice), reading from a list in Dutch orthography. The potential epenthetic stops were not written in the materials and were not discussed with the speakers. The speakers were simply instructed to pronounce the non-words in a natural way and as they were written. Thus, the speakers did not intend to produce epenthetic stops (in the sense of intending to produce a phoneme). Any epenthetic stops the speakers did produce are a matter of phonetic variability in speech production, rather than an intended part of the phoneme string.

	+ /p/	+ /t/	+ /k/	+ /s/
/m/	/frampo:f/	/frimti:l/	/flumke:m/	/fromsi:n/
	no epen.	[m(p)t]	[m(p)k]	[m(p)s]
/n/	/franpo:f/	/frinti:l/	/flunke:m/	/fronsi:n/
	[n(t)p]	no epen.	[n(t)k]	[n(t)s]
/ʔ/	/fraʔpo:f/	/friʔti:l/	/fluʔke:m/	/froʔsi:n/
	[ʔ(k)p]	[ʔ(k)t]	no epen.	[ʔ(k)s]

Table 1: Clusters with examples of stimulus materials.

For each token, presence or absence of a burst for the epenthetic stop was evaluated by examining the waveform and spectrogram using the XWaves software. We evaluated the frequency of epenthetic burst (rather than epenthetic stop) production because it is theoretically possible for speakers to produce an epenthetic stop with no burst detectable in the waveform or spectrogram. For nasal-/s/ clusters, however, a silent period before the onset of frication was taken as an epenthetic stop, even in the few cases with no visible burst.

2.2. Perception

A phoneme-monitoring experiment was carried out using

the productions by one speaker of the materials described above as stimuli. However, since the speakers produced epenthetic stops very rarely in clusters ending with /p/ (see 3.1 below), all clusters involving [p] (as the following obstruent or as an epenthetic stop) were omitted from the perception study, leaving the clusters /nt, nk, ns, ?t, ?k, ?s/. 24 native Dutch listeners were presented with the stimuli, interspersed with 183 fillers, and were asked to respond by pressing a button whenever they heard the sound /t/. 24 more heard the same materials but monitored for /k/. Reaction times and error rates (percent of stimuli responded to) were evaluated, but we will focus on error rates here. For further details of the methods, please see [1].

2.3. Lexical statistics

Lexical statistics on the number of words with epenthesis environments were obtained by searching the CELEX database [2] for all Dutch and English words containing the clusters in Table 1 (except those clusters which do not allow epenthesis, /mp, nt, ?k/). All word forms, rather than only distinct lemmas, were included, since epenthesis environments often occur when a stem ending in a nasal is followed by an inflectional morpheme (e.g. Dutch /zwem-t/ ‘swims’). The number of such words with each cluster in coda position (e.g. /zwemnt/) and the number with each cluster split across a syllable boundary (e.g. Dutch /?ʔʔʔʔʔ/ ‘anxious’) was counted.

3. RESULTS

3.1. Production: frequency of epenthesis

Both speakers produced epenthetic bursts less frequently in most medial clusters (split across a syllable boundary) than in most final clusters. (Data for final clusters is from [1].) Figure 1 shows the percentage of items containing epenthetic bursts for each cluster in medial and final position, averaged across the 14 items and all three productions. For six of the nine clusters, epenthesis is more frequent in final position. Although the small number of speakers does not allow a statistical analysis, there seems to be a trend toward more frequent production of epenthesis in final clusters. This result extends Blankenship’s finding that in English, epenthesis in /ns/ clusters is less likely if the cluster is split across a syllable boundary than if the cluster is within the coda [3].

3.2. Perception: effect of cluster position

Our main interest in this study is whether listeners perceive an epenthetic stop as a real token of the stop or not. In the phoneme-monitoring task, listeners were asked to respond whenever they heard a particular sound (/t/ or /k/). Thus, if a listener monitoring for /k/ responded to a stimulus /fli?p/ or /fra?po:f/, it can be concluded that that he/she perceived the epenthetically produced stop in the stimulus as a real token of /k/. (Reaction times to epenthetic stops were slower than to non-epenthetic stops [1], showing that listeners were not sure about epenthetic stops, but even so, when a listener responds that he/she heard the sound /k/ in /fra?po:f/, it must be concluded that the listener heard the epenthetic stop as an instance of /k/.) Figure 2 shows the proportion of stimuli of each cluster condition and each position for which listeners

responded that they heard the stop which could occur epenthetically in that stimulus. (This graph shows the proportion of, for example, /ʔs/ stimuli to which listeners monitoring for /k/ responded, the proportion of /ns/ stimuli to which listeners monitoring for /t/ responded, etc.)

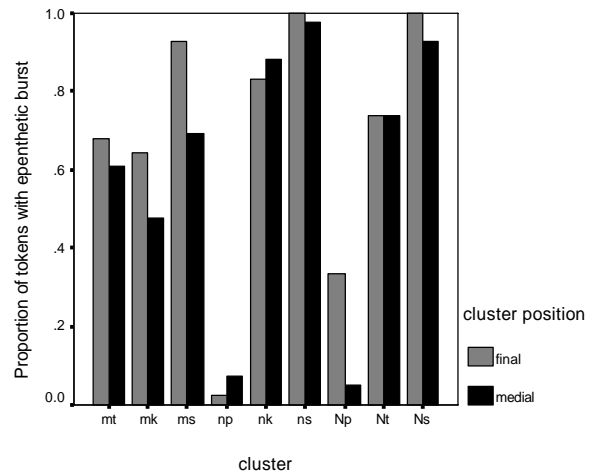


Figure 1: Proportion of tokens produced with epenthetic burst, by cluster and cluster position. “N” is used for “ʔ.”

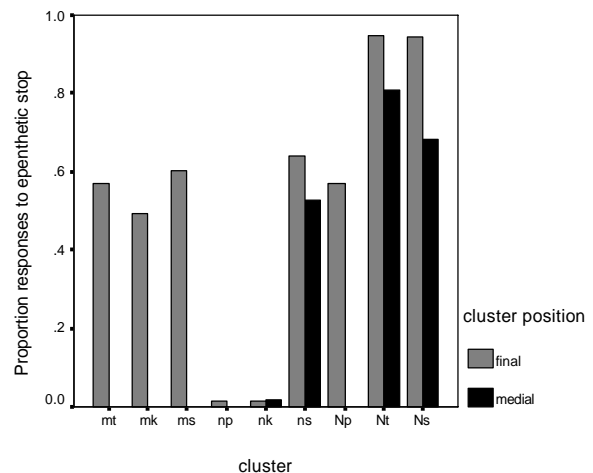


Figure 2: Proportion of stimuli in which listeners responded to the stop expected to occur epenthetically, by cluster and cluster position. “N” is used for “ʔ.” Only the clusters /nk, ns, ?t, ?s/ were used in medial position.

In the final cluster items used in [1], of the 9 clusters with an environment for epenthesis, 5 (/mt, ms, ns, ?t, ?s/) would form phonotactically possible final clusters in the language even if the epenthetic stop were fully, phonologically present (i.e. /mpt, mps, nts, ?kt, ?ks/ are possible final clusters of Dutch). The remaining 4 clusters (/mk, np, nk, ?p/), if the epenthetic stop were fully present, would violate a phonotactic constraint which forbids clusters of 3 consonants at the end of a syllable unless the final one is alveolar. The clusters /mpk, ntp, ntk, ?kp/ cannot occur at the end of a syllable in Dutch. For

example, /zʔkt/ 'he sinks' ends in /ʔkt/, but no word ends in /ʔkp/. In the medial clusters, however, none of the clusters violates a phonotactic constraint, even if the epenthetic stop is considered to be fully present. This is because the last obstruent of the cluster is in the onset of the following syllable, leaving only two consonants at the end of the preceding syllable (e.g. /ʔk.p/). Thus, /ʔkp/ does occur medially, as in /dʔʔkpro:ble:m/ 'thought problem.'

We first compared listeners' responses to medial cluster stimuli and to those final cluster stimuli which do not violate phonotactic constraints (/mt, ms, ns, ʔt, ʔs/). This allows us to determine whether listeners are more likely to perceive an epenthetic stop as a real stop when the cluster is in final or medial position, aside from the issue of phonotactic constraints. Since speakers' production of epenthetic stops is not equally frequent for the various conditions, and individual tokens vary greatly in the acoustic strength of the epenthetic stop, it is necessary to account for differences in production when evaluating perception across conditions. In order to do this, we measured several acoustic attributes of each stimulus token, included all the acoustic measures in a discriminant analysis, and then used the value of the discriminant for each token as the covariate in an analysis of covariance. This removes the influence of presence or absence and acoustic strength of the acoustic stop, and allows the analysis of covariance to test for an effect of medial vs. final cluster position on perception, independent of production differences. The acoustic characteristics we included in the discriminant analysis were epenthetic stop duration, duration of silence before the epenthetic stop, duration of the nasal, and the presence or absence of an epenthetic burst [1].

A planned comparison of the 5 final cluster conditions with no phonotactic violations (/mt, ms, ns, ʔt, ʔs/) to the 4 medial cluster conditions was conducted. The analysis of covariance showed that the medial clusters received significantly fewer responses to the epenthetic stops than the final cluster conditions did, even when adjusted for the discriminant ($F(1,168)=69.92, p<.001$). However, the /nk/ condition appears to be anomalous: it received very few responses to epenthetic [t] even though epenthesis is produced quite often in this condition (cf. Fig. 1). This is the case whether /nk/ is in medial or final position. This anomalous result may stem from facts about Dutch orthography, rather than from processing of epenthetic stops [1]. Since this condition may bias the results, and the low response rate for this condition is not well understood, we also conducted the same comparison without the (medial) /nk/ cluster. Again, medial clusters received significantly fewer responses to epenthetic stops ($F(1,168)=9.66, p<.005$).

The finding that listeners are less likely to respond to epenthetic stops in medial position, even when production factors and phonotactic constraints are controlled for, confirms a preliminary finding by Ali et al. [4] for English. They also found that listeners were less likely to hear epenthetic stops across syllable or morpheme boundaries, even when acoustic analysis confirmed that epenthesis had been produced.

3.3. Perception: effect of phonotactic constraint violations

Warner and Weber [1] found that listeners are less likely to respond to an epenthetic stop in final clusters if the presence of

the epenthetic stop would violate a phonotactic constraint than if it would not. When listeners hear an epenthetic stop, they must decide whether the speaker actually intended a stop (that is, the stop was fully phonologically present), or whether the speaker accidentally produced an epenthetic stop through overlap of the velic and oral gestures (that is, the stop was part of the acoustic variability of speech). The fact that listeners are more likely to respond to epenthetic stops when these would not violate phonotactic constraints indicates that listeners consider the phonology of their language when interpreting the normal phonetic variation inherent in speech.

However, epenthetic stops in medial clusters avoid violating phonotactic constraints in a different way than the phonotactically legal final clusters do: all the medial clusters are legal, because the third consonant joins the following syllable, whereas final clusters are only legal if they end in an alveolar consonant. In this section, we examine the validity of the phonotactic effect for the medial clusters.

As in section 3.2, we combined acoustic measures into a discriminant and used the discriminant as the covariate, but here we performed a planned comparison of the 4 medial cluster conditions to the 4 final clusters with a phonotactic violation (/mk, np, nk, ʔp/). Listeners responded significantly more often to the (phonotactically legal) medial clusters than to the (phonotactically illegal) final clusters ($F(1,168)=13.37, p<.001$). Excluding the anomalous /nk/ cluster, the result is similar ($F(1,168)=17.43, p<.001$). Thus, the effect obtained among the final clusters (fewer responses if the presence of the epenthetic stop would violate a phonotactic constraint) also holds when the phonotactic violation is avoided by means of making the cluster medial.

3.4. Lexical statistics: frequency of opportunities for epenthesis

In our experiment, we created opportunities for epenthesis to happen in each of several environments (every combination of the three nasals of the language plus /p, t, k, s/, both in medial and final position). However, these environments do not occur equally often in the actual lexicon of a language. The number of words containing such environments for epenthesis is likely to influence the frequency of epenthesis in actual speech. Furthermore, although past research shows that speakers of both American English and Dutch produce epenthesis rather often [1, 3, 5], the number of words in the lexicon with environments for epenthesis also differs across languages.

In order to investigate the frequency of opportunities for epenthesis in Dutch and English, we performed a search of the CELEX database [2] for all words containing the epenthesis environments investigated in this paper, as described in section 2.3 above. The number of words per 10,000 word forms in the Dutch and English databases with each environment for epenthesis, in medial and final position, appears in Table 2. (Counting words per 10,000 normalizes for the fact that the Dutch database contains more words than the English one.)

The clusters in which the epenthetic stop is phonotactically illegal (/mk, np, nk, ʔp/ in coda position) also violate a constraint even without the epenthetic consonant, and therefore there are no words containing these clusters in coda position. (The reason these clusters cannot occur in this position is that they combine consonants with different places of articulation, and the final one is not alveolar.) However,

each of these clusters occurs in a small number of words in medial position, in each of the two languages. Examples are “pingpong” (/ʔp/) and “kumquat” (/mk/) in English and “zangpedagoog” ‘voice teacher’ (/ʔp/) and “bloemkool” ‘cauliflower’ (/mk/) in Dutch.

Lang.	mt	mk	ms
Dutch	24.5 – 18.1	0.0 – 13.9	26.9 – 25.3
English	0.1 – 1.0	0.0 – 1.7	0.1 – 4.3
	np	nk	ns
Dutch	0.0 – 0.2	0.0 – 0.9	142.0 – 180.5
English	0.0 – 4.0	0.0 – 11.8	39.7 – 75.7
	ʔp	ʔt	ʔs
Dutch	0.0 – 2.5	4.3 – 4.3	98.8 – 21.6
English	0.0 – 4.3	0.0 – 1.1	0.1 – 4.4

Table 2: Number of words per 10,000 word forms in the CELEX database with each cluster in each environment. The first number in a cell is the number of words with the cluster in a coda (usually word-final), the second is the number with the cluster split across a syllable boundary (medial position).

Turning to the remaining clusters (the ones which are phonotactically legal even in coda position), it is clear that opportunities for epenthesis are far more common in the Dutch lexicon than in the English one. All the clusters /mt, ms, ns, ʔt, ʔs/ occur in more of the words of Dutch than of English, both in medial and final position. Only /ns/ is common in English. One reason for this lies in variation in inflectional morphemes: in English, the plural marker for nouns, the third person singular marker for verbs, and the possessive are all voiced /-z/ after a voiced segment such as a nasal (e.g. “moms,” “seems,” and “mom’s” respectively, all ending in /mz/). Similarly, the past tense morpheme is usually realized as /-d/ after a nasal, as in “seemed” (/md/). Thus, /ms, mt/ in coda position in English are restricted to a few exceptional words, such as “dreamt.” In medial position, these clusters occur, but usually in compounds, as in “homestead” (/ms/). Although epenthesis in a completely voiced cluster is possible, it is far less frequent than in a cluster with a voiceless obstruent [5]. In Dutch, however, the inflectional morphemes /-s/ (plural and possessive) and /-t/ (third person singular, also occurs in the past participle) are not voiced after nasals, leading to a very large number of words with the relevant clusters. In fact, these final obstruents can only be voiceless in Dutch, because of a general pattern of final devoicing. Examples are “albums” ‘albums’ (/ms/), “Adams” ‘Adam’s’ (/ms/), and “neemt” (/mt/ ‘takes.’

Thus, the phonological rules of English and Dutch lead to a great difference in the number of words containing an environment for epenthesis. If speakers often produce epenthesis when an environment for it occurs, one would expect to find a difference between English and Dutch in the frequency with which epenthesis occurs in natural speech. Indeed, this appears to be the case: investigation of epenthesis in English has been limited to the /ns/ cluster [3, 5] and to small numbers of words exhibiting other epenthesis environments (e.g. “Tecumseh” and other such words [4]). In Dutch, however, epenthesis occurs in many words with the final suffixes /-t, -s/ as well as in other words. Wetzels [6]

gives examples of epenthesis in words such as “hangt” (/ʔ(k)t/) ‘hangs’ and “hemd” (/m(p)t/) ‘shirt,’ and Warner and Weber [1] report audible epenthesis in approximately half of productions of such words. Epenthetic stops were even spelled in some of these words in an earlier version of the Dutch spelling system [6]. Epenthesis does indeed appear to be more widespread in Dutch than in English, except perhaps in the /ns/ cluster.

4. CONCLUSIONS

This study provides data on production and perception of epenthetic stops across syllable boundaries in Dutch. In doing so, it complements the data already available on epenthesis in syllable coda position. The comparison of production and perception data for both of these environments, and for the several clusters we test, provides a more thorough picture of epenthesis than has been available for any language in the past literature. The findings that epenthetic stops tend to be produced less frequently across syllable boundaries than in coda position, and that, even when produced, they are perceived less frequently in that environment, confirm and extend results in the past literature [3, 4].

Furthermore, this study shows that epenthetic stops are more likely to be perceived if they are in medial position (where they would not violate any phonotactic constraints) than if they are in final clusters where they would violate a constraint of the language. This extends previous work [1], and confirms the importance of the phonological system of the listener’s language in processing of phonetic variability such as epenthesis.

Finally, the lexical statistics presented in this paper demonstrate that even if speakers of both of two languages epenthesis quite often when an environment for epenthesis is present (as past literature has shown for both American English and Dutch [1, 3, 5]), there will be differences in how often epenthesis occurs in actual speech dependent on lexical characteristics of the languages.

5. REFERENCES

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