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Research article

# Variability in the implementation of voicing in American English obstruents

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ABSTRACT

Previous research has shown that in languages like English, the implementation of voicing in voiced obstruents is affected by linguistic factors such as utterance position, stress, and the adjacent sound. The goal of the current study is to extend previous findings in two ways: (1) investigate the production of voicing in connected read speech instead of in isolation/carrier sentences, and (2) understand the implementation of partial voicing by examining where in the constriction voicing appears or dies out. The current study examines the voicing of stops and fricatives in the connected read speech of 37 speakers. Results confirm that phrase position, word position, lexical stress, and the manner and voicing of the adjacent sound condition the prevalence of voicing, but they have different effects on stops and fricatives. The analysis of where voicing is realized in the constriction interval shows that bleed from a preceding sonorant is common, but voicing beginning partway through the constriction interval (i.e., negative voice onset time) is much rarer. The acoustic, articulatory, and aerodynamic sources of the patterns of phonation found in connected speech are discussed.



## 1. Introduction

Voicing in English obstruents is a much discussed topic in the phonetic literature. However, while many studies focus on voice onset timing (VOT) as a cue to voicing in stops (e.g., Lisker & Abramson, 1967; Zlatin, 1979), and others on cues such as the length of the preceding vowel (e.g., Raphael, 1972) or *F*0 at the obstruent offset (e.g., Hanson, 2009; Ohde, 1984), fewer studies report details about the realization of phonation during the constriction period of voiced obstruents. Yet, as discussed in Gonet (2010), popular textbooks of English phonetics nevertheless promulgate incomplete and anecdotal descriptions of how phonation during stop closures and frication periods is assumed to be implemented. According to these textbook authors, obstruents are only fully voiced in intervocalic position (and presumably word-medially, given examples such as 'lagging' and 'saving') (Cruttenden, 2008; Davenport & Hannahs, 2010) and are likely to have little phonation at all in initial or final position (e.g., 'bill', 'done', 'cub', 'lid') (e.g., Ball & Rahilly, 1999; Catford, 2001; Cruttenden, 2008; Davenport & Hannahs, 2010). For most of these descriptions, the authors do not distinguish word-initial and final from phrase-initial and final positions, though the examples suggest that these claims about voicing are pertinent primarily to words produced in isolation.

Taken together, these descriptions raise more questions than they answer, since there are many conditioning factors such as word position, phrase position, adjacent consonants, and lexical stress that could affect the proportion of voicing present during obstruent constrictions. Thus, one goal of this paper is to examine the effect of these variables on where and how much voicing is produced during obstruent constrictions (stop closures and the frication portion of fricatives) in American English connected speech. (Note that throughout this paper, 'voicing' will be used synonymously with 'phonation', to indicate the presence of vocal fold vibration during obstruent constrictions.) Another goal is to gain a clearer understanding of how 'partial voicing' is implemented. As will be reviewed in more detail in the following section, a number of studies have observed that English voiced obstruents may be partially voiced in some environments. Most accounts of partial voicing seem to treat it as phonation lasting less than 100% of the closure duration, but a major drawback of this usage is that it does not characterize where voicing occurs during the closure. In this study a large number of obstruents are examined to address not only which segmental and prosodic factors condition voicing during the constriction of

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voiced obstruents, but also what shape the typical partial voicing patterns take for stops and fricatives produced in connected (read) speech.

### 1.1. The realization of voicing in English obstruents: findings and limitations

In spite of the relative vagueness in textbooks, a number of studies provide information aimed at quantifying the proportion of voicing in English obstruents. A particularly extensive study is Docherty (1992), who examined the production of phonation in obstruents in Southern British English. The target stimuli were produced in three environments—in isolation, in a "voiced carrier" phrase that provided a vowel-adjacent context on the left for initial obstruents and on the right for final obstruents, and in a "voiceless carrier" phrase that likewise provided a voiceless obstruent context. Results for voiced stops in word-initial position showed that they were completely devoiced in isolation and in the voiceless carrier phrase, and that the vast majority of tokens in the voiced carrier phrase were partially voiced (with some tokens being fully voiced). Word-initial stops were often voiced for more than half of the closure (but the location of this voicing within the constriction was not investigated). Final stops showed a somewhat different pattern; even in isolation and the voiceless carrier phrase, the large majority of tokens showed at least partial and occasionally full voicing.

Fricatives in word-initial position (excluding /ð/, which patterned almost completely like a voiced stop) were more evenly split among completely voiced, completely voiceless, and partially voiced, except that the voiced carrier phrase tended to condition more completely voiced tokens. Voiced fricatives in word-final position were most often produced with partial voicing, though the overall amount of voicing was lower than for initial fricatives, with an increase in full voicing in the voiced carrier phrase. From this data, Docherty concludes that the definition of the phonological category 'VOICED' is more complex than had been thought, and that "many aspects of the realization of voicing timing are not predictable from the nature of the voicing category (129)".

While the results in Docherty (1992) are extremely informative, there are still some limitations to this study. First, carrier phrases were used, which may not reflect how voicing is implemented in more connected speech (i.e. reading of semantically coherent text, or spontaneous speech). Second, when Docherty calculated the proportion of voicing, he collapsed fully voiced and partially voiced tokens, which may obscure how partial voicing is actually realized. Third, as explained previously, Docherty only considered the total proportion of voicing, but not where in the obstruent constriction it is actually realized (though an impressionistic account of this is discussed in his Chapter 5). Fourth, these data focus on obstruents in word-initial and final position, but do not include results for word-medial obstruents. In fact, these limitations generally hold true for all of the following studies that will be reviewed, except where noted. Finally, Docherty's data are for Southern British English.

Beyond Docherty, other studies provide some conflicting information about the realization of voicing in voiced stops or fricatives. Starting with voicing in post-pausal, word-initial position (often referred to as 'prevoicing'), Lisker and Abramson (1964,1967) observed stops with both prevoicing and short-lag voice onset time in American English, but the prevoiced tokens were effectively found only for one of their four speakers. Similarly, Keating (1984) found that words with post-pausal initial /b/ read by two speakers were occasionally produced with prevoicing, but by and large they were implemented with short lag VOT and no phonation during the closure. On the other hand, other authors have found that half or more of post-pausal voiced stops are produced with some prevoicing (Flege, 1982; Smith, 1978; Westbury, 1979).

As for intervocalic position, most studies have shown dramatically higher rates of full voicing for American English, often between 80% and 90% (Flege & Brown, 1982; Keating, 1984; Westbury, 1979). The patterns for British English are similar (Suomi, 1980), but Suomi also found that even when a stop is between two vowels, word position matters; when words were produced in a carrier phrase, intervocalic stops at the end of a word were partially voiced substantially less often than intervocalic word-initial stops. Similarly, Jacewicz, Fox, and Lyle (2009) found that the degree of emphasis of a word in a phrase affected the proportion of voicing produced for /b/ in inter-sonorant position; the proportion of voicing was greater for words with less emphasis than words with more emphasis. Interestingly, this result was true for the speakers from Wisconsin in this study, but not the speakers from North Carolina, who had very high rates of voicing in this environment regardless of target word emphasis. This is a clue that prosodic factors are one consideration that can have a potential effect on how much voicing is realized in English obstruents.

Like the studies of stops, research dealing specifically with fricatives in English confirms that the implementation of voicing depends on whether a fricative is adjacent to a vowel or sonorant, or to an obstruent or a pause, regardless of its voicing specification (Gonet, 2010; Haggard, 1978; Smith, 1997; Stevens, Blumstein, Glicksman, Burton, & Kurowski, 1992). For example, Smith (1997) found that word-final American English /z/ was much more likely to be fully voiced if it was between two sonorants (including vowels), as compared to preceding a voiced stop. Regarding adjacent stops, there was still more partial voicing for adjacent voiced stops than voiceless ones. As for word position, sentence final /z/ was always devoiced, whereas phrase-medial /z/ (regardless of word position) was dependent on the surrounding context, as already described. Very similar patterns were also reported in Haggard (1978), who examined all of the British English fricatives. Haggard includes the additional information that the fricative /ð/ is generally more voiced in all environments than all other fricatives, and /z/ is mostly devoiced when between stressed vowels. Taken together, these studies demonstrate that fricatives lose some degree of voicing next to pauses or obstruents, and that lexical stress likely also plays a role in how voicing is realized.

In general, the number of studies that provide some information about the realization of voiced obstruents in connected speech contexts is small. For English, Gonet and Swiecinski (2012) examine the voiced obstruents of four speakers of British English taken from interviews in word-initial, word-medial, and word-final contexts. They measure the total percentage of completely devoiced tokens of fricative and obstruent constrictions. Gonet and Święciński find a number of variables that condition devoicing: word-initial position, a preceding or following obstruent, being in a stressed syllable, and coda position.