

## Is Voicing of English Voiced Stops Active?\*

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### ABSTRACT

Phonetic voicing does not support the phonological distinction of voiced/voiceless in English stops. The present study is aimed at defining the nature of voicing of English voiced stops. A review of the literature reveals that the voicing is position-conditioned and its length is notably inconsistent relative to the closure duration. No consistent relationships are found between vocal fold adduction and glottal pulsing in initial position. Stress reduced the voicing, etc. The hypothesis for experiments was: (1) active voicing: stress generates longer (stronger) voicing during the closure duration of a voiced stop; (2) passive voicing: stress induces shorter (weaker) voicing during the closure. Instead the voiced stop becomes more voiced when the preceding vowel (syllable) is stressed. The literature review and the results of two experiments comparing English and Slovakian suggested that the voicing of English voiced stops is passive (i.e., a coarticulation of glottal pulsing for adjacent vowels – syllables) and should be distinguished from active voicing in some other languages.

**Keywords:** Voiced Stop, Active vs. Passive Voicing, Coarticulation

### 1. Introduction

English oral stops consist of (1) phonologically voiced lax unaspirated /b, d, g/ and (2) voiceless tense aspirated /p, t, k/. Among the three distinctive features: voicing, tensivity and aspiration, voicing has been the prime feature of English stops. This is why most of the literature uses just voiced/voiceless dimension when briefly introducing English oral stops. However, the distinction of voiced and voiceless is not practically operative in initial and final position of English stops, which is well reflected in a short question: “Are b, d, g voiced plosive?” (Roach, 2001, p. 35).

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Furthermore, the feature voicing loses its function as a phonetic cue for the English voiced stop in intervocalic position as well (Kim, 1989). So, some authors have claimed that the feature voicing should be replaced with the feature tensity (e.g., Malécot, 1970; Kim, 2002).

Despite many observations of the inconsistency between phonetic voicing and phonological voicing in English stops, there have been surprisingly few indications about the nature of voicing itself in the published literature. Therefore, the present study investigates the characteristics of voicing in English voiced stops. As a first step, we suggest two types of voicing in voiced stops. One is **active voicing**: independent voicing of a voiced stop. The other is **passive voicing**: a continuation or coarticulation of glottal pulsing for adjacent vowels or syllables. In general, in order to generate voicing during the hold phase of stops, it is necessary to maintain the transglottal pressure difference with the lightly adducted vocal folds with some muscular tension. It can be achieved by means of the appropriate subglottal air pressure; the expansion of the oral cavity or the increase of the pharynx volume (Chomsky & Halle, 1968; Netsell, 1969; Perkell, 1969; Westbury, 1983; Ohala, 1983). These conditions should be actively met if the voicing in a stop is active. Now, our question is whether the voicing of English voiced stops is active or not. Through a review of the literature and some experiments, this study will show that voicing of English stops is passive, and how it differs from active voicing in some other languages.

## 2. Voicing of English Voiced Stops: Literature Review and Experiments

According to the definition of voicing in stops, the closure duration of English voiced stops should be fully voiced regardless of their position. However, full voicing is not general even in intervocalic position with positive phonetic environments for voicing, as well as in initial and final positions. In relation to this, Kim (1989) reported that English intervocalic voiced stops yielded voicing ranging from 9% to 100% of closure duration, with a standard deviation of  $\pm 31.085$ . Taking into account full devoicing in initial position together, the range of voicing in English voiced stops expands up to 0% – 100% and the standard deviation will increase, too. Besides, against some writers' expectation (Gleason, 1955; Klatt, 1975; Ohala, 1983), short closure in intervocalic lax stops does not necessarily induce full or longer voicing (Kim, 1989). Hence, the inconsistent duration of voicing in lax stop closure will be

evidence for passive voicing of English lax stops, because active voicing is expected to be significantly consistent particularly in the phonetically positive environments. The result of an informal experiment using spectrograms of CSL (Computerised Speech Lab) with an English nonsense isolated word /ada/ revealed great inconsistency between two British male subjects, with one producing full voicing during the closure of /d/, the other nearly full devoicing. Furthermore, even the subject who showed full voicing produced nearly full devoicing in the same speech item in another experiment.

Second, as far as partial voicing is concerned, in intervocalic and final positions it always begins from the end of the preceding vowel (the onset of stop closure) and tapers to die somewhere prior to the release of stop closure. In contrast, in initial positions it appears just before the release of stop closure and continues into the following vowel. It is noteworthy that in initial position there is no vowel before stops, i.e., no source of voicing. In particular, the voicing contrast between English /p/ and /b/ is not significant in utterance-initial position (Flege & Brown, 1982). Why does partial voicing of voiced stops appear on both sides of a vowel, with very short on its left and long on its right? This may indicate that voicing of English lax stops is passive.

Third, in a study to examine the timing of vocal fold adduction and phonation onset in initial English stops, Flege (1982) found no consistent relationships between vocal fold adduction and glottal pulsing in voiced stop /b/ (see Figure 1). If the voicing in initial /b/ is active, a considerable amount of voicing and more systematic relationships between vocal fold adduction and glottal pulsing should be discovered. On the other hand, speaker 9, who was bilingual in Spanish and English, showed no lag between adduction and onset of glottal pulsing. Flege speculated that the result was due to the influence of Spanish in which prevoicing is an important perception cue of voiced stops. Unlike English speakers, Spaniards may actively produce voicing during voiced stops – active voicing; therefore, voicing onset coincides with adduction.

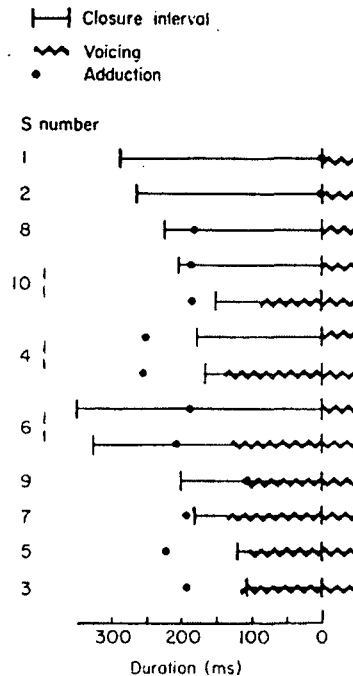


Figure 1. Individual patterns shown by ten speakers during production of *bay*. Vocal fold adduction is indicated by the filled circle, glottal pulsing by the wavy line, and stop closure/release by vertical lines. Three speakers (10, 4, 6) showed two patterns of production (from Flege, 1982, Figure 4, p.187 with permission from Elsevier).

Fourth, it is interesting that Flege & Brown (1982, p. 341) measured “the continuation of voicing from the preceding vowel into the closure interval” as voicing for post-stressed English /p/. If so, one may ask why the voicing during the closure phase of /b/ should not be considered as “the continuation of voicing from the preceding vowel into the closure interval”. Will the answer be that voicing of the preceding vowel can go into the following lax stop /b/ more easily than into /p/, or that voicing of the preceding vowel does not go into the following lax stop /b/? When the muscular tension of the vocal folds is weak (lax) and the opening of the vocal folds is neutral (i.e., a state that the vocal folds can be easily affected by adjacent sounds), preceding vowels will very likely influence following lax stops and continue their voicing partly or fully during the following lax stop closure.

Fifth, advocates of the feature voicing in English voiced stops insist that despite devoicing, the vocal folds are often adducted, which they call potential voicing (Lisker & Abramson, 1967; Catford, 1977). They seem to interpret the vocal fold adduction as an active movement for voicing. The only consistency Flege (1982) observed in the production of initial /b/ was laryngeal timing: vocal fold adduction generally

occurred before stop release. However, the adducted vocal folds do not always guarantee vibration, whereas abducted vocal folds do not necessarily mean voicelessness. That is, the vocal fold adduction is just a favourable condition for glottal pulsing. Relating to this, it is interesting to refer to Kagaya's (1974) fiberoptic and acoustic study of Korean obstruents. As seen in Figure 2, the vocal folds for the Korean tense unaspirated stops (/p<sup>h</sup>e/, /p<sup>i</sup>/, /t<sup>h</sup>e/, /t<sup>i</sup>/, /k<sup>h</sup>e/, /k<sup>i</sup>/) are adducted in initial position. But they do not produce voicing. Rather, the vocal folds for some intervocalic lax stops (/epe/, /ete/, /eke/), which are abducted at the beginning part of the closure (see Figure 3), will vibrate.

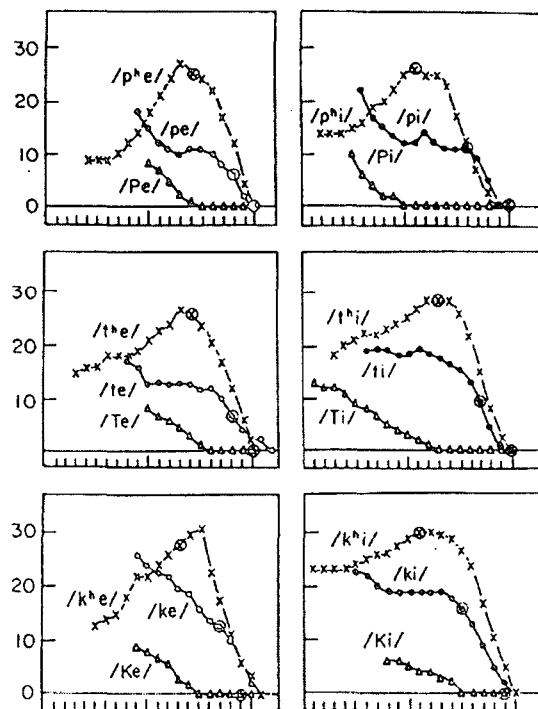


Figure 2. Temporal changes of glottal width for representative utterance samples of each type of the stops in /CV/ (from Kagaya, 1974, Figure 2, p. 164 with permission from Elsevier).

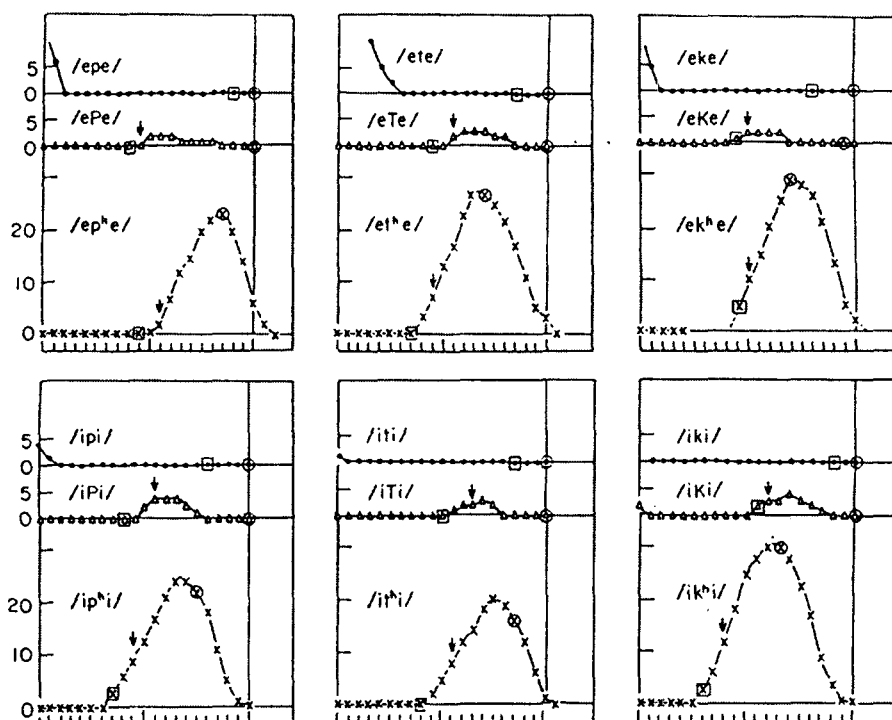


Figure 3. Temporal changes of glottal width for representative utterance samples of each type of the stops in /VCV/ (from Kagaya, 1974, Figure 3, p. 165 with permission from Elsevier).

In English, as in /h/ of “ahead”, breathy voice is observed in spite of the slightly abducted vocal folds (Ladefoged, 1982, p. 129). Some stops in many Indian languages like Hindi have breathy or whispery voice during the aspiration (i.e., voice onset time) which means the vocal folds are abducted (Ladefoged, 1982; Catford, 1977). Why should the adducted vocal folds be regarded only as potential voicing? What counts is whether the adduction is actively obtained for voiced stops. The consistent laryngeal timing Flege (1982) reported might be for the following vowel, not for the initial voiced stops that do not differ from their voiceless cognates in voicing. The adduction of vocal folds could be only a condition to be easily influenced by adjacent vowels, or a (passive) state already affected by them rather than the potential (active) voicing of lax stops.

Sixth, stress (more articulatory energy) generally causes voicing of a phonologically voiced sound to become longer and/or stronger. Interestingly, however, Kim (1987) reported that stress reduced voicing of English intervocalic voiced stops. In relation to this, he defined the presence of any voicing period of a lax stop as a function of the feature [lax], and devoicing of a tense stop as a function of the feature [tense]. Here we set up a hypothesis concerning stress effects on each of the active and passive

voicing. One is **active voicing**: in some languages (e.g., Slovakian), stress generates longer (stronger) voicing during the closure phase of a voiced stop (if it were originally fully voiced, the voicing bar in a spectrogram would manifest itself as darker and thicker due to stress). The other is **passive voicing**: in some other languages (e.g. English), stress induces shorter (weaker) voicing during the closure (i.e., the voicing bar in a spectrogram would manifest itself as shorter and fainter due to stress). Instead the voiced stop becomes more voiced when the preceding vowel (syllable) is stressed, i.e., assimilation or coarticulation.

In order to test the hypothesis, an experiment using a CSL and a recorder was accomplished with Slovakian and English. Slovakian belongs to languages where the feature voicing is operative in their stops phonetically as well as phonologically (Comrie and Corbett, 1993). In contrast, the distinction of voiced/voiceless in English stops is phonological rather than phonetic. The test word was “bulldog” (“buldog” in Slovakian) commonly used in both languages. This speech item has all three lax stops /b, d, g/ with different places of articulation. Though the sound preceding the medial stop /d/ is not a vowel, the environment of /d/ can be regarded as the same as in intervocalic position, because the lateral /l/ is voiced enough. A Slovakian female and a British male in their thirties served as subjects. They pronounced the test word, giving stress on each syllable alternately in a recording room. The results turned out to be contrastive between the two languages. First, as seen in Figures 4 and 5, the Slovakian initial stop /b/ and intervocalic /d/ revealed generally darker and/or longer voicing bars when they were stressed than unstressed (the final /g/ is excluded from comparison, since Slovakian voiced stops are addressed as voiceless aspirated stops in final position – neutralization). This indicates that voicing of Slovakian voiced stops is **active**. On the other hand, Slovakian words have stress on their first syllables. Hence, it could be somewhat unnatural for the Slovakian subject to put stress only on the second syllable “dog” of the speech item. But the influence on the results looks negligible, i.e., the characteristics of active voicing are clearly observed. Secondly, in English, (1) the initial stop /b/ was voiceless regardless of stress, (2) the voicing bar of the intervocalic stop /d/ was generally darker and longer when it was unstressed (i.e., the preceding vowel was stressed) than when it was stressed (i.e., the following vowel was stressed), and (3) the final stop /g/ was more voiced when the preceding vowel was stressed than unstressed (see Figures 6 and 7). Considering these results in contrast with those in Slovakian, we can interpret the phonetic voicing in English lax stops as assimilation (coarticulation) into the voicing of the preceding vowel (syllable) i.e., **passive voicing**.

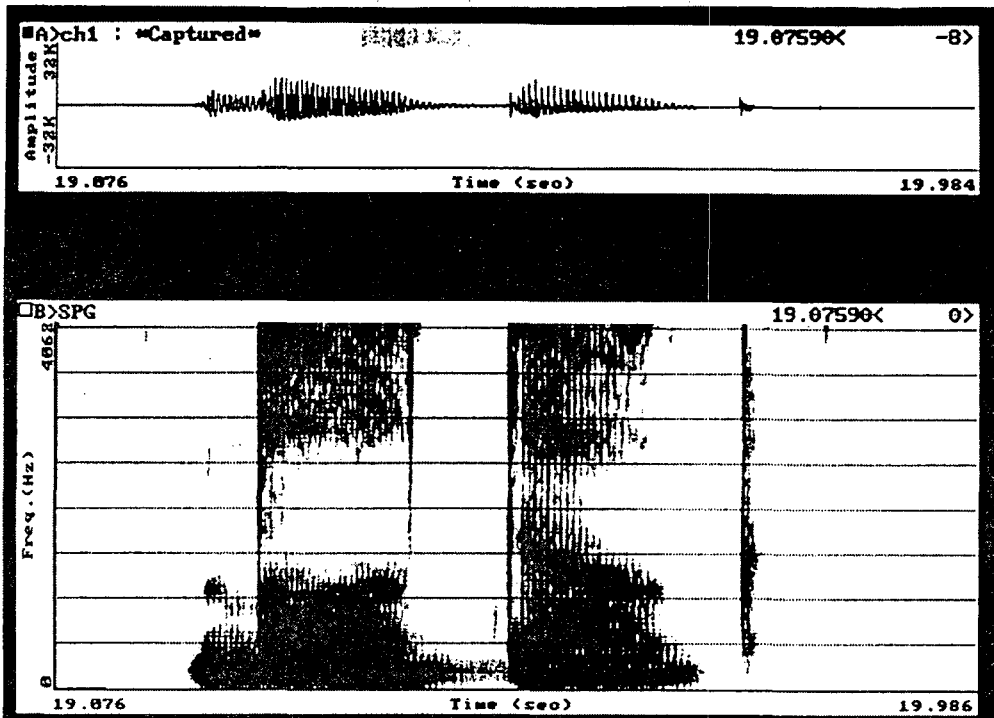


Figure 4. A spectrogram of Slovakian “buldog” with stress on the first syllable.

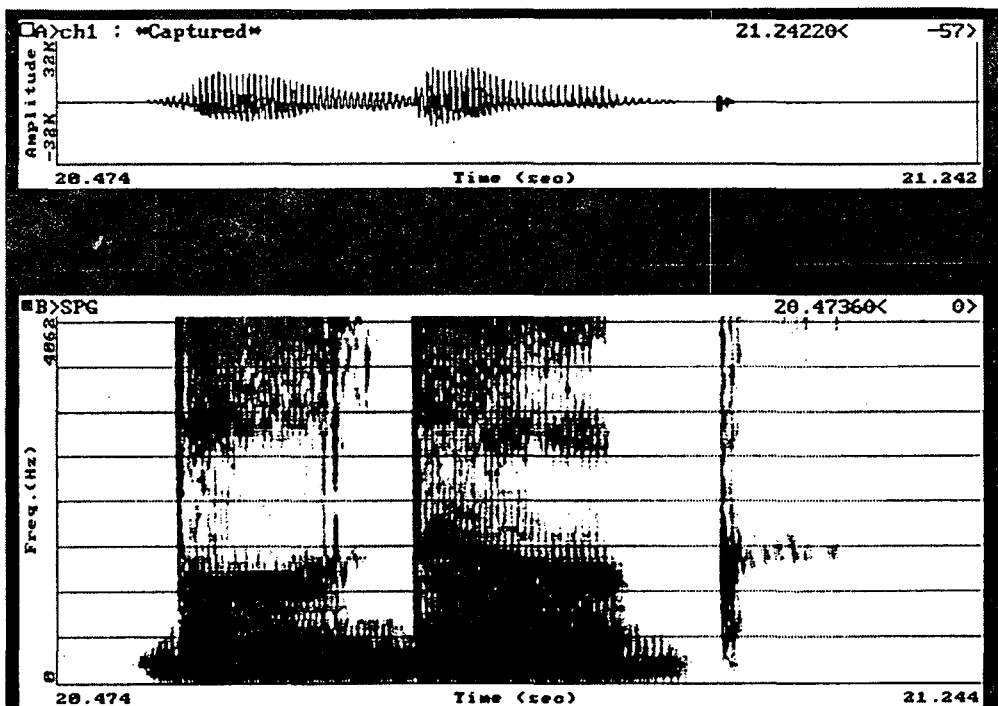


Figure 5. A spectrogram of Slovakian “buldog” with stress on the second syllable.



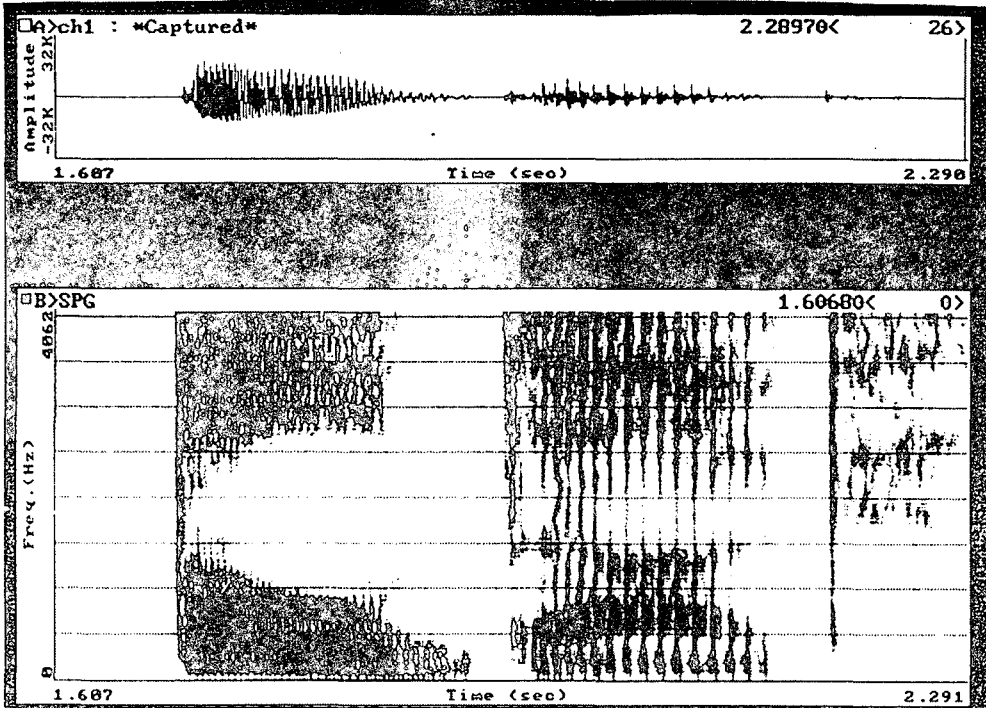


Figure 6. A spectrogram of English “bulldog” with stress on the first syllable.

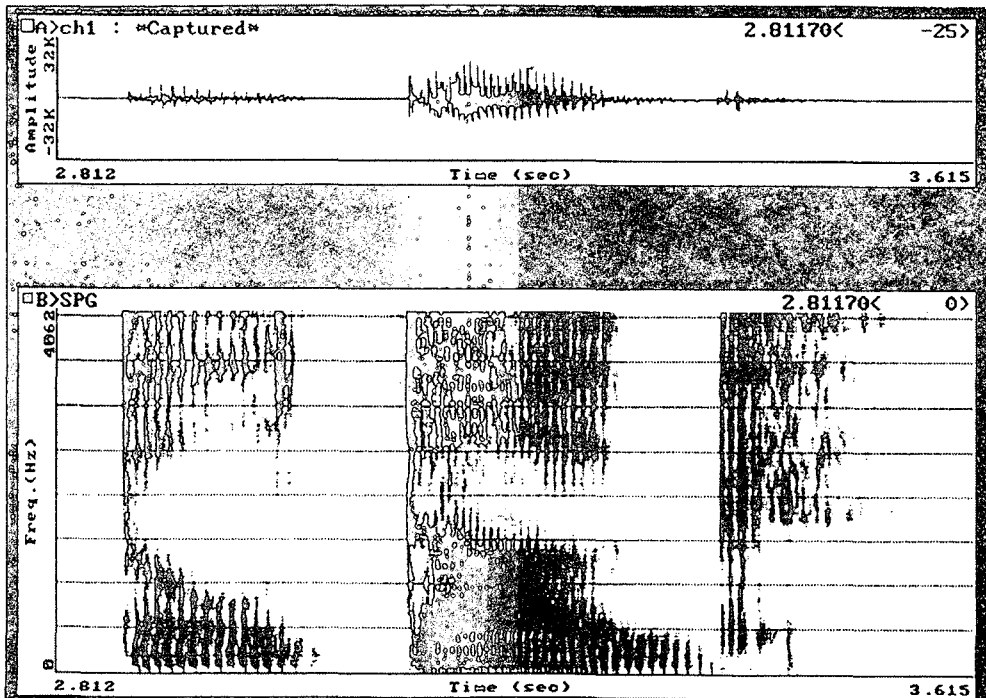


Figure 7. A spectrogram of English “bulldog” with stress on the second syllable.

We went on to examine some more Slovakian speech items (e.g., “guma”, “dedo”, “zuby”, “baba”, and “obed”). The Slovakian female speaker stressed each syllable of the words alternately. The results were identical to that of “bulldog”. That is, in contrast to English, stressed Slovakian voiced stops were characterised by darker and longer voicing, and all intervocalic voiced stops were fully voiced irrespective of stress. For instance, Figures 8 and 9 show the case of “baba” (an old woman). On balance, voicing during the closure in Slovakian stops looks to be independent, whereas voicing in English stops seems to be dependent especially on the preceding voiced sounds. The presence or absence of stress on the preceding vowel (or syllable) is likely to be directly associated with the voicing of the following stops in English, but not in Slovakian. This hypothesis focusing on the relationship between stress and voicing will be used as a principle to differentiate the two types of voicing (active vs. passive).

Seventh, with regard to the active vs. passive voicing, one more experiment was carried out. The above two British males and Slovakian female were asked to speak “Asda” /azda/, ‘a supermarket’s name in the UK’. The word has a stress on its first syllable and the four phonemes are all phonologically voiced. Recording was made using a recorder and a microphone in a sound treated recording room. Spectrograms were obtained through a CSL. First, both of the British subjects fully devoiced the stop /d/ of /azda/ (see Figure 10 out of subject 1 who fully voiced the /d/ of /ada/ in the earlier informal experiment). This means that the voiced stop /d/ became devoiced after the voiced fricative /z/, i.e., a favourable condition for voicing. Apparently voicing of the initial stressed vowel /a/ did not affect the stop /d/ across /z/. The phonologically voiced fricative /z/ frequently shows partial devoicing (Smith, 1997). Conceivably, the voicing of /z/ was not powerful enough to continue into the following stop /d/. In other words, English voiced stops are less likely to become voiced when the voicing of a preceding sound is not strong enough. This also indicates that voicing of English voiced stops is passive. On the other hand, Figure 11 clearly shows that the Slovakian female produced active voicing in /d/ after /z/, which is in sharp contrast to the /d/ in Figure 10.

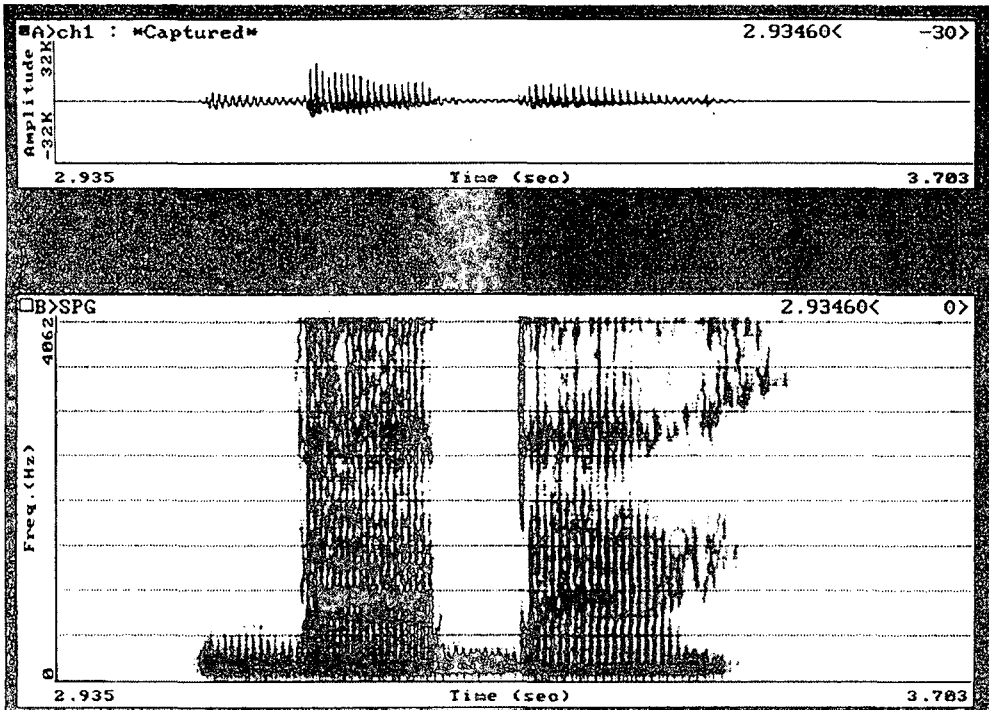


Figure 8. A spectrogram of Slovakian “baba” with stress on the first syllable.

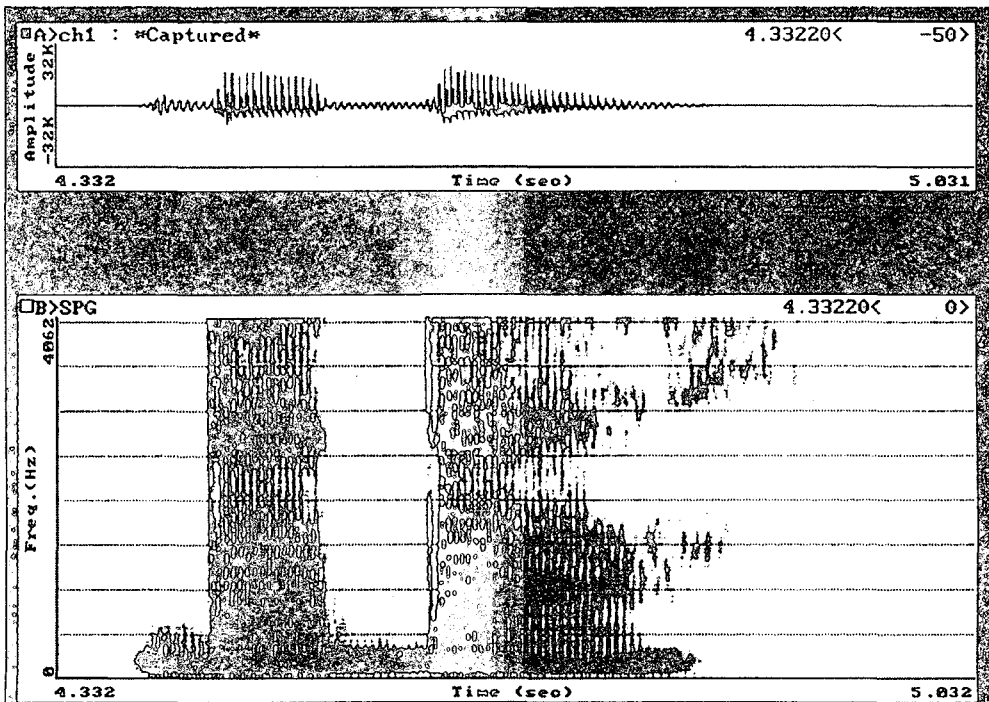


Figure 9. A spectrogram of Slovakian “baba” with stress on the second syllable.

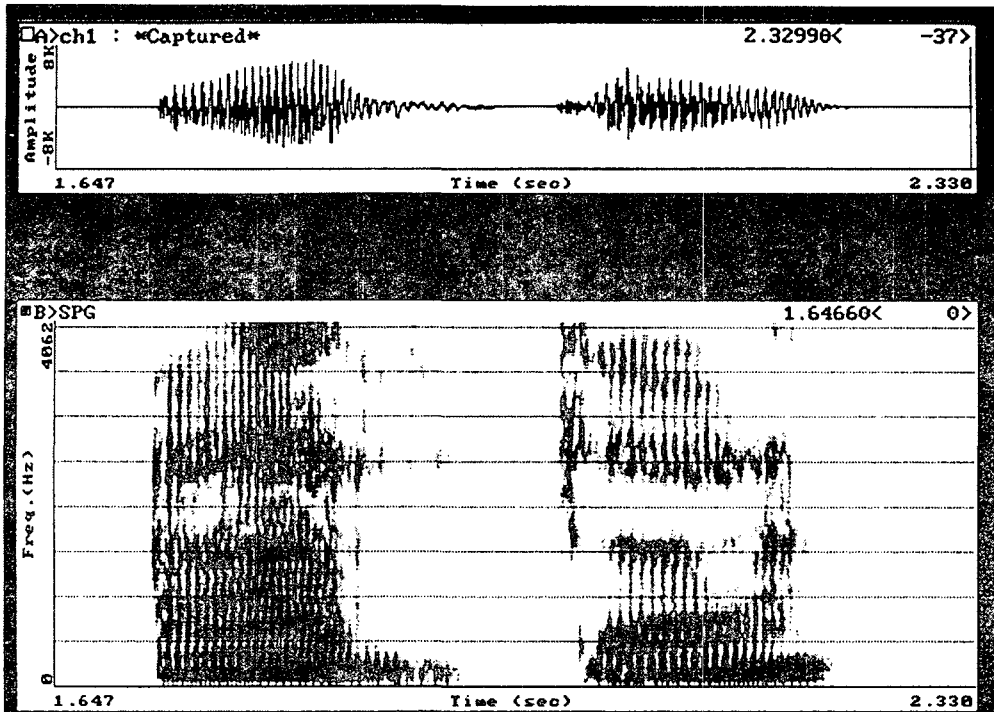


Figure 10. A spectrogram of “Asda” /azda/ pronounced by a British male.

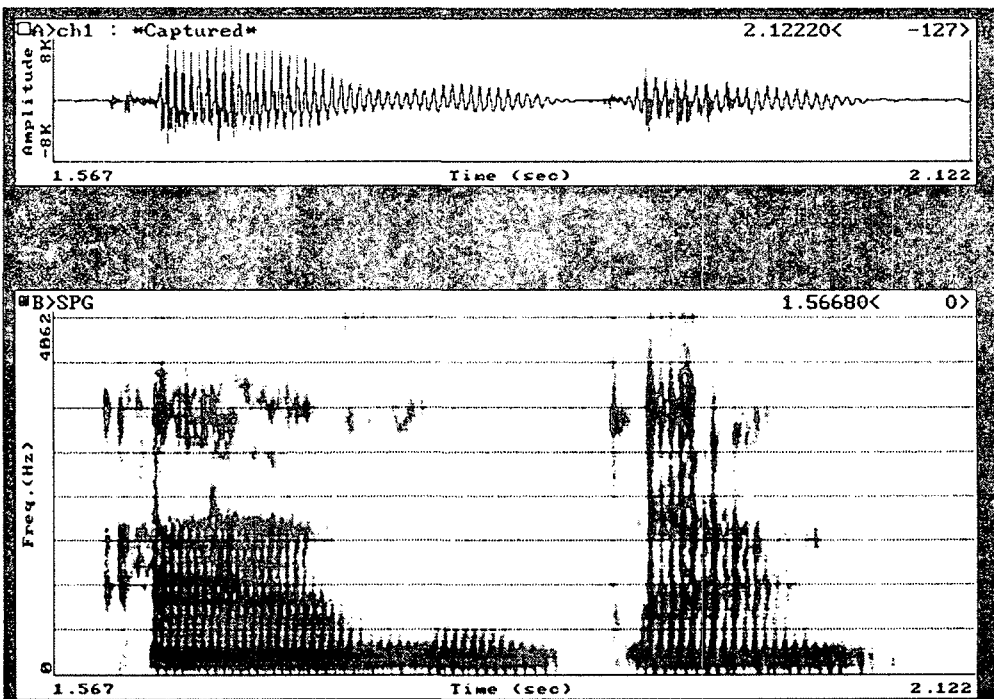


Figure 11. A spectrogram of “Asda” /azda/ pronounced by a Slovakian female.

### 3. Summary and Conclusion

Though voicing is regarded as the primary feature to distinguish English stops /b, d, g/ and /p, t, k/, phonetic voicing is not a reliable cue for the phonological distinction. The present study was targeted at defining the nature of voicing in English voiced stops. A review of the literature suggested that the voicing of English voiced stops is not active. First, the voicing is position conditioned, and the duration of voicing relative to the stop closure is remarkably inconsistent. Second, voicing appears mainly on the right side of a vowel. Third, no consistent relationships are found between vocal fold adduction and glottal pulsing in initial voiced stop /b/. Fourth, the lightly adducted vocal folds are said to be potential voicing, but this could be also a condition to be easily influenced by adjacent vowels, or a (passive) state already affected by them. In addition, the results of the two experiments confirmed that voicing of English voiced stops is passive. First, English voiced stops showed notably less voicing when the following vowel (syllable) was stressed than unstressed. Rather they became much more voiced when the preceding vowel (syllable) was stressed than unstressed. Second, English voiced stops became devoiced even after a stressed vowel when a sound with weak voicing (e.g., a voiced fricative [z]) was inserted. On the other hand, Slovakian stops, voicing of which is believed to be active, yielded results opposite to those of English. Considering the literature review and the results of experiments, it is concluded that the voicing of English voiced stops is passive (i.e., a continuation or coarticulation of glottal pulsing for adjacent vowels) and it should be differentiated from active voicing in some other languages. Accordingly, we can define two kinds of voicing during the voiced (lax) stop closure. One is **active voicing**: stress on a voiced stop enhances its voicing. Voicing onset coincides with adduction in initial stops (e.g., Spanish). The other is **passive voicing**: stress on a voiced stop (the following vowel) decreases its voicing. Instead the voiced stop becomes more voiced when the preceding vowel (syllable) is stressed. Voicing onset is not correlated with vocal fold adduction in initial stops.

Provided all utterances involve coarticulations – the overlapping of adjacent articulation, one may presume that voicing of English voiced stops is a sort of glottal coarticulation (assimilation). A sound (e.g., a vowel) with strong glottal pulsing would affect a neighbouring sound (especially a following lax stop). Conversely, a tense stop can partly devoice preceding vowel depending on the relative power of articulation (e.g., Kim (1987) observed average 10 ms predevoicing before the onset of oral closure of English intervocalic voiceless stops). One may further speculate that the

inherent feature of so-called voiced lax stops in English is not voiced but voiceless. As they become stronger (stressed), they may be restored to their inherent voicelessness. But the presence/absence of voicing does not have phonemic relevance in English stops (Port, 1979; Flege, 1982). If so, what makes stops /b, d, g/ phonologically voiced may not be the silent vocal fold adduction but English speakers' perception. As far as English phonology is based on perception, English stops /b, d, g/ will be voiced and /p, t, k/ voiceless irrespective of their phonetic manifestation. However, phonology should not be independent of phonetics. This is why light should be shed on the reality of voicing of English voiced stops. Our interest surrounding the distinctive feature voicing in English stops will have to move from how long the voicing during the closure lasts or how consistent it is to whether the voicing is active or passive, since this seems to be more fundamental than that. The distinction between active and passive voicing of voiced stops will be meaningful from the phonological as well as phonetic point of view – the passivity of voicing of English voiced stops critically weakens the status of voicing as the primary distinctive feature.

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