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An EMG Study of the Feature 'Tensity'

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= Abstract =

Previous studies reveal that in English there is no EMG evidence for the feature tense-lax distinction. The technique of electro-myography(EMG) was used to see if the existing claim holds true, particularly in unstressed syllable. It was found that in unstressed syllable, the peak EMG amplitude from the orbicularis oris superior muscle was significantly greater in /p/ than in /b/, while in stressed syllable this difference was negligible. It was hypothesized that in stressed syllable, /p/ and /b/ may be differentiated by the EMG activities from a muscle other than the orbicularis oris superior muscle, e.g. the respiratory muscles relating to 'aspiration' or depressor anguli oris muscle. In Korean, there was a clear labial gestures for the feature tense-lax distinction. The phoneme-sensitive manifestation of stress and some possible reasons for the inter-speaker variability in the data and the variability within a given speaker were discussed.

KEY WORDS : tense-lax distinction · EMG.

Introduction

The existing literature reveals that there are two types of claims associated with the EMG activities from the orbicularies oris superior muscle in bilabial stops of English : 1) The orbicularis oris muscle activity is essentially the same for English /p/ and /b/(e.g. Harris, et al. 1965 ; Tatham and Morton, 1968 ; Tatham, et al. 1985 ; Lubker and Parris, 1970 ; Sussman, et al. 1973) and 2) in sorld-final position of the isolated /CVC/ words, /p/ and /b/ were differentiated by the peak EMG amplitude, but not in word-initial position(Fromkin 1966).

Fromkin(1966) used the inconsistent EMG results in rejecting a linguistic hypothesis of tense-lax distinction on the basis of a hypothesis that 'if muscular gestures for /p/ and /b/ are either identical or if there is no consistent relationship, a feature other than the tense-lax feature must distinguish these two phonemes, e.g., the action of the glottis"(p 170). In previous studies, however, the possible effects of stress on the EMG activities have been relatively neglected(e.g. for CVCV/VCVC utterances, Harris, et al. ; for CVC utterances, Fromkin, 1996 ; for CV/VC/VCV utterances, Lubker and Paris, 19 70 ; CVC/VCV utterances, Tatham, et al., 1985). Although the difference was not always stable, it appears from Table 1(Lubker and Parris, 1970) that, in unstressed syllable, there is a clear tendency to a higher EMG activity in /p/ then in /b/. The isolated monsyllable word of English is considered to be produced with stress on it, and in the /C_1VC_2/

context, the effect of stress on the muscular activities may be linked more closely to C_1V- than -VC_2(MacNeilage and Declerk 1967 ; Tatham and Morton, 1968). Considering this, the isolated speech items with /CVC/ structures, used by Fromkin(1966), appear to be improper for her claim.

This study was designed mainly 1) to see if the EMG activities from the orbicularis oris superior muscle are essentially the same for /p/ and /b/ of English, 2) to determine the effects of stress on the EMG activities exerted by the obicularis oris superioris muscle for the labial closure and 3) to examine the claim(Kim 1980 ; Kim 1965) that in Korean EMG activities from the obicularis oris superioris muscle were significantly greater both in the tense aspirated /p^h/ and in the tense unaspirated /p/.

In this study, the feature tensity has been defined as the amount of muscle action(or energy) used in producing a phoneme. According to his conception, the tense stop should be characterized either by a longer EMG activity or by a greater peak EMG gesture or by both. The articulatory correlates of the feature tensity are time and amplitude. It is hypothesized that the distinctive feature "tense-lax' distinguishes /p/ from /b/ in English and /p^h, p^l/ from /p/ in Korean, with English /p/ and Korean /p^h, p^l/ being tense, and Korean unaspirated /p/ and English /b/ lax.

Method

1. Subjects

Three(1 American and 2 Korean) of five subjects were used. Two subjects(a British and a Korean) were rejected because of small amplitude of EMG signals throughout trial runs, thus yielding unsatisfactory recordings. The subjects used had no speaking problems.

2. Speech Items

As seen in Table 1, in order to minimize the effects of coarticulation, rounded and spreaded vowels were avoided. The speech items were produced in isolation rather than in a carrier phrase, since the temporal or spatial extent of coarticulation is not yet precisely known.

The speech materials with the /CVCV/ syllabic structure were produced under controlled experimental conditions, stress being one of them. In order to obtain natural data in unstressed syllables, an attempt was made to construct natural word-like /CVCVC/ items in pair, such as 'balloon', 'palloon', 'perhaps', and 'berhaps'. The /CVC/ items of English and the /VCV/ items of Korean were used to see if the claims(Fromkin 1966 ; Kim 1980) hold true. Each isolated speech item was produced five times at a normal(or moderately slow) speech rate, yielding a total of 80 utterances in English (/CVC/=20, /CVCV/=40, real-word-like /CVCV/=20), but ten times in Korean, giving 30 utterances.

Table 1.

English /CVCV(C)/ items	English /CVC/ items
/bəl^{l}u : n/ /pəl^{l}u : n/ /bərh^{l}æps/	/bʌb/ /pʌb/
/bəb^{l}ʌ/ /pəb^{l}ʌ/ /b^{l}ʌbə/ /b^{l}ʌbə/	/bʌb/ /bʌp/
/b^{l}ʌbə/ /p^{l}ʌbə/ /bəb^{l}ʌ/ /bəb^{l}ʌ/	
Korean /VCV/ items : /apa/ /ap^{l}a/ /ap^{h}a/	

(Korean /p/=a lax unaspirated stop, /p^h/=a tense aspirated stop, /p^l/=a tense unaspirated stop).

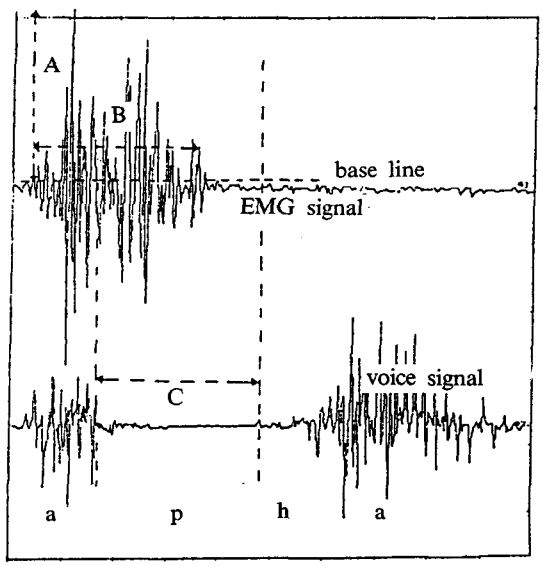


Fig. 1.

3. Procedure

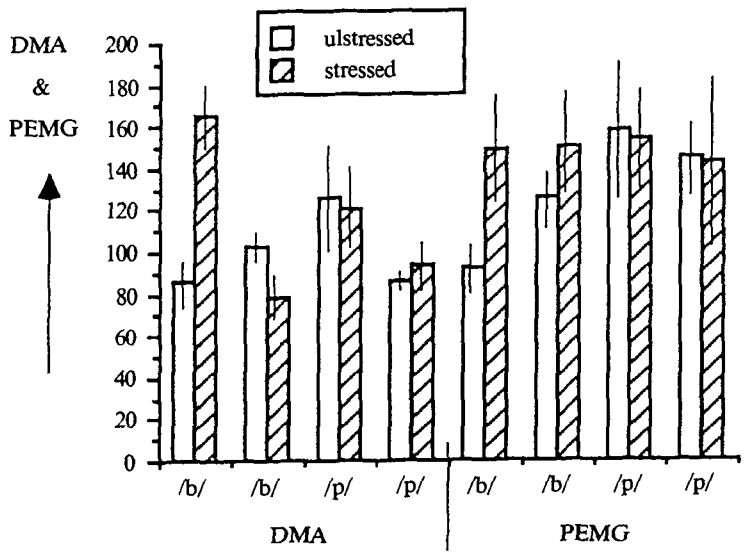
For subject training, preparations prior to the test session and measurement, the method used in Tatham(1985) was duplicated. Simultaneous raw voice signals and electromyographic records, using an electro-myograph(QUANITUM 84, CADWELL CO.) and an audio microphone, were obtained from surface electrodes on the upper lip of each of three speakers as they produced bilabial consonants contained within the isolated speech items.

Two dependent parameters were measured(see Fig. 1). A) The peak of the EMG amplitude in μV : the distance from the noise floor to the peak EMG amplitude trace, B) the duration of muscle action in ms : the interval from onset of activity to cessation of activity, and C) the duration of oral closure in ms : for the unaspirated stops, the interval from the offset of regular pulse to the onset of the regular pulse in the voice signal, but for the aspirated stops, the interval from the offset of the regular pulse to the onset of explosion in the voice signal. Since in word-initial stops of English, the reference line for the onset/offset of the oral closure was not clear-cut in the voice signal, the measuring of the oral closure interval was excluded in English. Statworks was used on a Macintosh P. C. for the statistical analysis. This experiment was undertaken at the Pusan National University Hospital.

Results on Discussion

Phoneme-sensitive EMG manifestations of stress in English

As seen in Fig. 2, the effects of stress on the peak EMG amplitude of the orbicularis oris superior muscle for the labial closure for /b/ was highly significant although for the case with the word-final position there were some overlaps($p<.075$). The peak EMg amplitude for /b/ was much greater(overall average 37%) in stressed syllables than in unstressed syllables. However, this diffrence did not oc-



The first /b/s and /p/s in the section of DMA and PEMG were the C_1 and the second ones C_2 in the /C_1VC_2V/ word where the vowel in stressed syllables was /ʌ/ and in unstressed syllables /ə/.

Fig. 2. Diagram showing the effects of stress on the duration of muscle action(DMA) in ms and the peak EMG amplitude(PEMG) in μV in the English /b/ and /p/, and vertical lines indicate standard deviations ($n=5$).

cur in /p/, and the effects of stress on the duration of muscle action were inconsistent both in /b/ and in /p/. Thus, the effects of stress on the peak EMG amplitude appeared to be phoneme sensative.

At this point, one may ask a question : What would be the valid EMG measure for the manifestation of stress in /p/ ? Previous studies reveal that in the English /p, t, k/ VOT was significantly greater in stressed syllables than in unstressed syllables while this difference was negligible in /b, d, g/(e.g. for BrEng intervocalic stops, see Kim, 1987 ; for AmEng word-initial stops, see Lisker and Abramson, 1967). Thus, the stress-related aspiration was also phoneme-sensative but in an opposite direction to the case with the lip muscle gestures.

Considering the phoneme-sensitive phenomena associated with the peak EMG amplitude and the aspiration, one can presume that in /p/ the manifestation of stress may be carried out by the EMG activity from a muscle other than the orbicularis oris muscle gestures, e.g., the respiratory muscle activities relating to aspiration. The phoneme-sensitive EMG manifestations of stress, which have been relatively neglected in the previous studies, may be one of reasons for the variability in the EMG data relating to the orbicularis oris superior muscle.

Stress-Sensitive EMG gestures in English

Fig. 3 shows that in unstressed syllables of the /CVCV/ words and the /CVCVC/ words, /p/ and /b/ in word-initial position were highly significantly differentiated by the peak EMG amplitude exerted by the orbicularis oris superioris muscle : the peak amplitude tiated by the peak EMG amplitude exerted by the orbicularis oris superioris muscle : the peak amplitude was greater(overall average 32%) in /p/ than in /b/, but in word-final position there

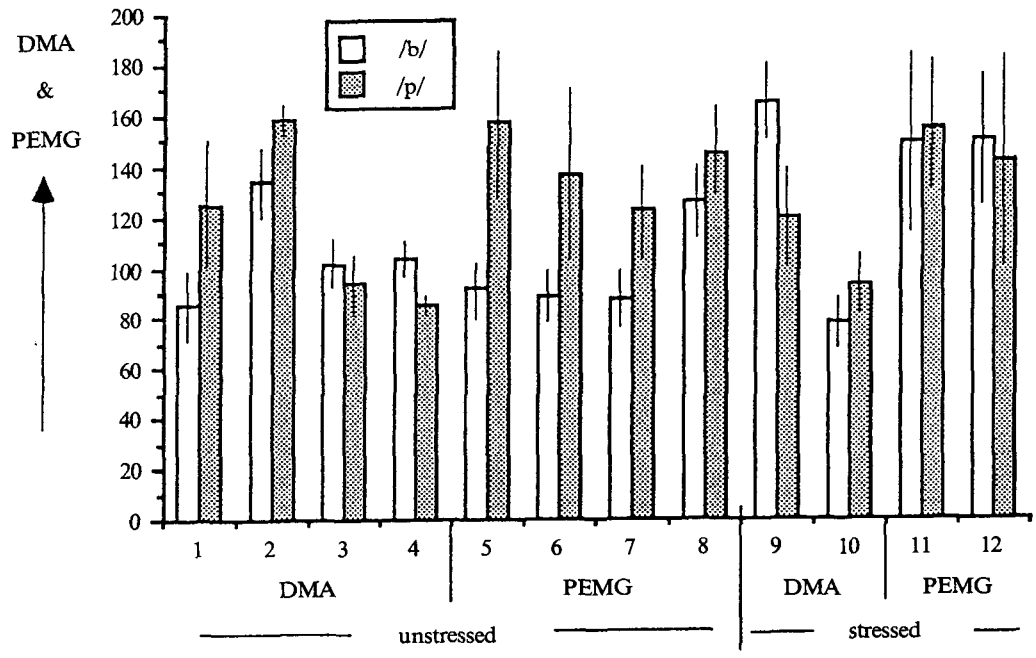


Fig. 3. Diagram showing mean durations of muscle action(DMA) in ms and the mean peak EMG amplitude (PEMG) in μV for the English /b/ and /p/ in unstressed an stressed syllables(n=5). Vertical lines indicate standard deviations.

were some overlaping in the peak EMG amplitude between /b/ and /p/($p<.08$). However, in stressed syllables the peak EMG amplitude was essentially the same for /p/ and /b/. The figure also demonstrates that the duration of muscle action was an invalid measure for /p/-/b/ distinction, regardless of the placement of stress.

Thus, the hypothesis that the EMG feature 'tense-lax' differentiates /p/ from /b/ in English, with the English /p/ being tense, and the English /b/ lax has been verified in unstressed syllables only. This is in contrast with the existing claims(e.g. Fromkin 1966 ; Lubker and parris 1970 ; Harris et al., 1965 ; Tatham et al. 1985). This difference may be due mainly to the fact that the previous studies have relatively neglected the effect of stress on the EMG parameters. Considering the inter-muscle difference(Sussman et al. 1973) and the greater degree of aspiration in /p/ than in /b/, one may assume that in stressed syllables English /p/-/b/ distinction may be carried out by the EMG activities from a muscle other than the orbicularis oris superior muscle, e.g. the depressor anguli oris muscle or the respiratory muscle relating to aspiration.

Inter-muscle differences Sussman, et al.(1973) found that /p/ and /b/ were significantly differentiated by the depressor anguli oris muscle, but not either by the orbicularis oris superior muscle or by the quadratus labii superior muscle. This means that not every labial muscles, involved in producing the stops, were activated simultaneously to distinguish /p/ from /b/.

Inter-muscle compensation In Sussman, et al. (1973), one of the two subjects did not use his jaw to any great extent during the speech inventory, even for open vowels. He showed the high degree of negative correlation between jaw elevation for the medial consonant and EMG activity in mentalis to elevate the lower lip for the stop.

Phoneme-sensative EMG gestures in Korean

As shown in Fig. 4, the timing variables and the peak EMG amplitude from the orbicularis oris muscle were significantly greater in /p^{l}/ and /p^{h}/ than

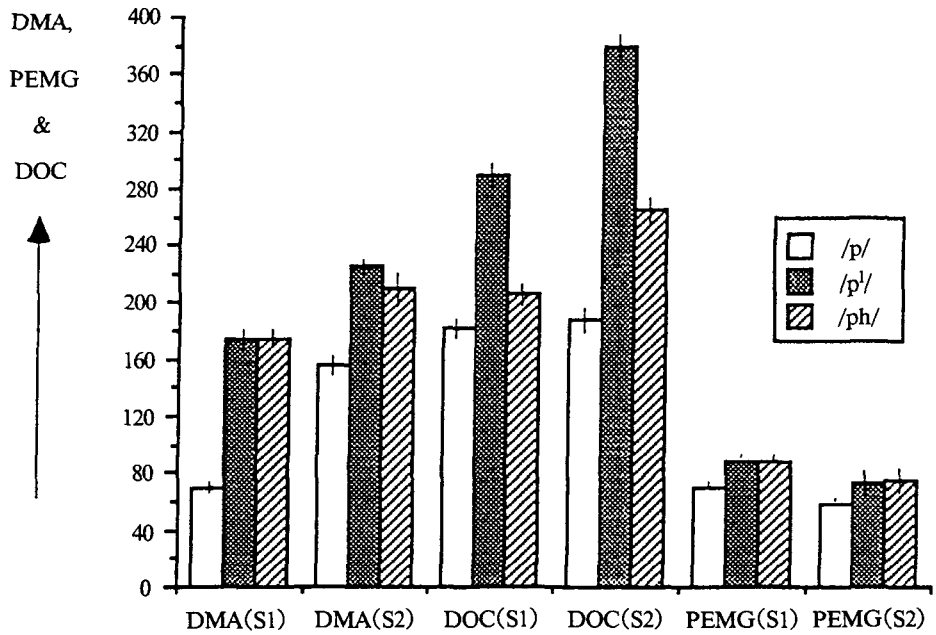


Fig. 4. Diagram showing the mean duration of muscle action(DMA) in ms, the mean duration of oral closure (DOC) in ms, the mean peak EMG amplitude(PEMG) in μV, and standard deviations(vertical lines) for the three types of Korean stops /p, p^{l}, ph/ and each subject(n=5).

in /p/, regardless of speaker, while for the two tense stops this difference was insignificant, except for the duration of oral closure. These findings are agreeable with the previous studies(e.g. for intervocalic position, Kim 1980 ; for word-initial position, W. Kim 1965). Thus, the hypothesis that the EMG feature 'tense-lax' distinguishes /p^h, p^l/ from /p/ in Korean, with the aspirated /p^h/ and the unaspirated /p^l/ being tense and the unaspirated /p/ lax has been verified.

There are contrastive claims over the criterion of distinction among Korean stops. Lisker and Abramson(1964) insisted that the voicing lag, i.e. aspiration, must be the primary opposing feature among the three series of the Korean stops while Kim (1965) claimed, "In Korean stops, tensity is the primary feature, the feature the occupies the higher node in the phonological hierarchy of stops, and the voice onset timing the secondary"(p356). However, the three types of stops could be differentiated from each other neither by aspiration nor by tensity. As pointed out by Kim(1980), you need 'aspiration' and 'tensity' simultaneously in distinguishing the three types of Korean stops as seen below :

Conclusion Although it is difficult to arrive at a conclusion due to the small number of informants, on the basis of the findings it was tentatively hypothesized 1) that the feature tense-lax distinguishes the stop consonants, with English /p/ and Korean /p^h/ and /p^l/ being tense, and Korean unaspirated /p/ and English /b/ lax, except for the case with the stressed syllable in English, 2) that in stressed syllables /p/ and /b/ of English may be differentiated by the EMG activities from a muscle other than the orbicularis oris superior muscle, e.g., the depress anguli oris muscle or the respiratory muscles relating to aspiration, 3) that the effects of stress on the peak EMG amplitude was phoneme-sensative, 4) that the subject variability in the data may have something to do in part with the inter-muscle difference and the inter-muscle compensation, 5) that the inconsistent EMG data within a given subject may be due in part to the phoneme-sensitive EMG manifestations of stress and 6) that the speaker would activate at least one of physiological parameters involved in producing a phoneme so that the selected parameter could distinguish /b/ from /p/.

Table 2.

Features	Lax unasp. (/p, t, k/)	Tense asp. (/p^h, t^h, k^h/)	Tense unasp. (/p^l, t^l, k^l/)
Aspiration	−	+	−
Tensity	−	+	+

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