KINEMATICS OF LIP AND JAW CLOSING MOVEMENTS DURING BILABIAL STOP CONSONANT PRODUCTION: EFFECTS OF UTTERANCE LENGTH AND WORD POSITION

Ludo Max
Laboratory for Speech Physiology and Motor Control
Department of Speech-Language Pathology and Audiology, Seton Hall University, South Orange, USA

ABSTRACT

This study is part of a larger project investigating the individual and combined effects of word position, utterance length, and phonetic context on kinematic aspects of labial and mandibular movements during grammatically correct and semantically meaningful utterances. In the present study, the effects of word position and utterance length on kinematic measures of movement duration, movement extent, peak velocity, and time to peak velocity during bilabial closing gestures for the stop consonants /p/ and /b/ were examined. Analyses revealed no statistically significant effect of word position. Utterance length, on the other hand, had a statistically significant effect on most of the dependent variables under investigation. Such effects were observed in the kinematic signals associated with movements of the individual articulators (upper lip, lower lip, or jaw) as well as in a mathematically derived signal of lip aperture.

1. INTRODUCTION

Despite continued research endeavors across a variety of disciplines, many aspects of the neuromotor organization of articulatory movements during speech production remain unknown. In many investigations of speech motor control, subjects are instructed to repeatedly produce a number of utterances consisting of nonsense words (e.g., VCV sequences) that may or may not be embedded in a carrier phrase. Valuable information has been gained through this approach and the effects of several independent variables (such as, for example, consonant voicing, vowel context, and articulation rate) on the kinematic characteristics of articulatory movements have been documented [1, 2, 3]. There appears to be an urgent need, however, to study these movements involved in speech articulation also under ecologically more valid conditions and to investigate the effect of various variables associated with those conditions on the organization and control of the performed movements.

The present study is part of a larger project investigating the individual and combined effects of word position, utterance length, and phonetic context on kinematic aspects of labial and mandibular movements during grammatically correct and semantically meaningful utterances. Specifically, this report includes the results from preliminary analyses completed to examine the effects of word position and utterance length on those labial and mandibular movements involved in the closing gesture during the production of bilabial stop consonants.

2. METHOD

1.1. Subjects

Ten adult speakers with no present or past communication or neurological problems served as subjects for the study. Subjects ranged in age from 26 to 46 years with a mean age of 34 years. Seven males and three females were included. All were native speakers of American English.

1.2. Procedure

Each subject produced 5 trials of each of 16 target utterances that were developed to represent three levels of utterance length. Level I consisted of a two-syllable CVCVC utterance combining the word "My" and one of the target words "bob," "bomb," "pipe," or "pop" (e.g., "My bob," "My pop"). Level II consisted of a four-syllable utterance in which the initial CVCVC sequence was identical to one of the utterances used at Level I (e.g., "My bobby-pin," "My poppy-plant"). At level III, the same CVCVC sequences from Level I were used in the initial (Level III-Initial) or final (Level III-Final) part of a longer and more complex utterance (e.g., "My bobby-pin was designed by an artist" and "An artist designed my bobby-pin," respectively). For each subject, all 80 utterances (4 conditions x 4 targets X 5 trials) were presented in randomized order on a computer monitor at a subject-controlled rate. A total of 11 productions, distributed across subjects, were unavailable for analysis due to subject error or technical difficulties.

Superior-inferior movements of the upper lip, lower lip, and jaw were transduced using a head-mounted strain gauge system [3] and digitized at 3KHz with 16-bit resolution. Off-line automatic software algorithms were used to measure (a) movement duration, (b) movement extent [i.e., amount of structural displacement], (c) peak velocity, and (d) time to peak velocity [i.e., time interval from movement onset to peak velocity] for the upper lip, lower lip, and jaw as well as for a derived signal of lip aperture (Figure 1).

Analysis of Variance (ANOVA) with repeated measures on Word Position (initial versus final) and Utterance Length (Level I versus Level II versus Level III-Initial) was used to analyze this subset of the data statistically. Separate tests were completed for each articulator and each dependent variable and Huynh-Feldt ϵ corrections were applied to each test to account for potential violations of the sphericity assumption. In order to meet the assumptions underlying ANOVA, subjects' data were first averaged across identical target words within each condition (see Max & Onghena [5] for an overview of some potential statistical problems with previous studies of this nature).

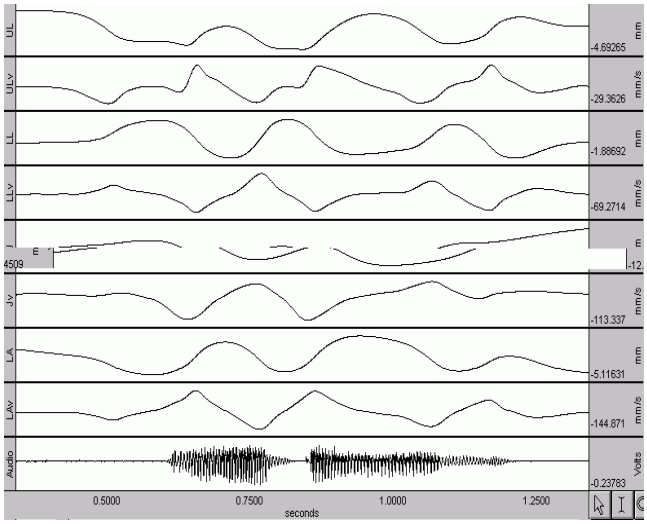

Figure 1. Illustration of Upper Lip, lower Lip, Jaw, and Lip Aperture position (UL, LL, J, LA) and velocity (ULv, LLv, Jv, LAv) traces during production of the Level I utterance "My bob" by a female subject.

3. RESULTS

1.1. Effects of word position

No statistically significant (α=.01) effects of word position were observed for any of the dependent variables as applied to any of the individual articulators or to the lip aperture signal.

1.2. Effects of utterance length

In contrast to word position, utterance length had a strong effect on almost all the kinematic parameters under investigation and this effect was observed in the signals for each of the individual articulators as well as in the mathematically derived representation of lip aperture. For movements of the upper lip, statistically significant (α=.01) effects of utterance length were observed for movement duration, movement extent, and time to peak velocity. For the lower lip, movement extent, and time to peak velocity reached statistical significance. For jaw movements, significant effects were found for movement extent and peak velocity. Lastly, the lip aperture signal showed statistically significant effects in movement extent and peak velocity. An interesting observation is that in most cases where the effect of utterance length was not statistically significant, probability values were less than .05.

4. DISCUSSION

This study investigated the effects of word position within an utterance and utterance length on a small set of kinematic parameters for the bilabial closing gestures associated with production of the stop consonants /p/ and /b/. Preliminary analyses failed to reveal any statistically significant effects of word position. Utterance length, on the other hand, was found to have a statistically significant effect on most of the dependent variables under investigation. These effects were observed in the kinematic signals associated with movements of the individual articulators (upper lip, lower lip, or jaw) as well as in a derived signal of lip aperture.

It has been well-known for several years that longer utterances tend to be produced with faster articulation rate than shorter utterances [6,7]. However, the exact mechanisms underlying such effects of utterance length on acoustic, kinematic, and electromyographic aspects of speech production are still poorly understood at this time. The line of research of which this report is one part, may contribute to an increased understanding of the neuromotor processes involved in such temporal as well as spatial articulatory adjustments. Work currently in progress in our laboratory is exploring the potential effects of word position, utterance length, and phonetic context in more detail and with inclusion of (a) both closing and opening gestures, and (b) parameters reflecting both intragestural and intergestural aspects of speech motor control.

ACKNOWLEDGMENT

This research was supported by USPHS Grant DC 03102.

REFERENCES

[1] Löfqvist, A., & Gracco, V. L. (1994). Tongue body kinematics in velar stop production: Influences of consonant voicing and vowel context. *Phonetica, 51,* 52-67.

[2] Löfqvist, A., & Gracco, V. L. (1999). Interarticulator programming in VCV sequences: Lip and tongue movements. *Journal of the Acoustical Society of America, 105,* 1864-1876.

[3] Barlow, S. M., Cole, K. J., & Abbs, J. H. (1983). A new head-mounted lip-jaw movement transduction for the study of motor speech disorders. *Journal of Speech and Hearing Research, 26,* 283-288.

[4] Max, L., & Onghena, P. (in press). Some issues in the statistical analysis of completely randomized and repeated measures designs for speech, language, and hearing research. *Journal of Speech, Language, and Hearing Research*.

[5] Ostry, D. J., & Munhall, K. G. (1985). Control of rate and duration of speech movements. *Journal of the Acoustical Society of America, 77,* 640-648.

[6] Fónagy, I., & Magdics, K. (1960). Speed of utterance in phrases of different lengths. *Language and Speech, 3,* 179-192.

[7] Malecot, A., Johnston, R., & Kizziar, P. (1972). Syllabic rate and utterance length in French. *Phonetica, 26,* 231-251.