COARTICULATION OF SPEECH AND SMILE MOVEMENTS

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1 Introduction

Facial expressions and speech movements can impose conflicting demands on speech articulators. For example, the bilabial closure for stop consonants /p/, /b/, and /m/ compete with the lip spreading and opening associated with smiling and laughing. Anecdotal evidence suggests this conflict may at least in some cases resolve as labiodental stop variants [1], though this discussion has been controversial (see [2], p. 18). Instances of conflict such as this can be useful in determining underlying control mechanisms in speech [3, 4, 5].

A simple model of coarticulation – one of unmediated superposition of muscle activations [6] – predicts that the outcome of this conflict may be determined by summing opposing forces due to competing muscle activations. In such a model, varying degrees of smile and varying degrees of closure force (e.g., for different stop consonants) should be expected to produce distinct outputs. Closures for /m/, /b/ and /p/ are known to vary (increasingly) in both intraoral pressure [7] and muscle force [8].

For the present paper, a pilot experiment is presented in which different bilabial stops are produced simultaneously with varying degrees of smile. Given the variation in muscle activation between the three stops and different degrees of smile, we predict that coarticulatory interactions in smiled speech will result in bilabials with lower activation such as /m/ being labiodentalized more often than bilabials with greater activation. Similarly, we predict that degrees of labiodentalization will vary depending on the strength of smile articulation. Finally, sequences with bilabials preceding or following a phonemic labiodental will benefit from the adjacent activation and have the highest chance of becoming labiodentalized.

2 Methods

Two native English speakers were recruited as participants in this study. Participants were seated in an experiment chair with a mirror positioned to their left to capture a side profile of the face and asked to read aloud 31 different sentences under three different facial conditions – neutral, smiling, and laughing. Sentences were presented in increments of five seconds; after every ten sentences, fifteen-second breaks were provided to reduce participants' facial muscle fatigue. Although absent from the present analysis, muscle amplitude of utterances under all three smile conditions was measured using surface electromyography electrodes placed on each participant's upper lip (in the vicinity of orbicularis oris) and cheek (in the vicinity of zygomaticus major) to be analyzed in future research. Each participant was asked to read the list of sentences once under each of the three smile conditions. The sentence list was structured such that five sentences per target sound was used, each containing a word where the bilabial consonant /b/, /p/, and /m/ was in a post-vocalic, word-final position.

Five sentences with target words containing the labiodental fricative /f/ and the bilabial glide /w/ in a post-vocalic, word-final position were also included. To examine the coarticulatory effects of adjacent bilabial/labiodental segments, five sentences with target words containing this series (ex. /bv/, /pf/) were added to the sentence list. Target words in all sentences were controlled for frequency and stress and rounded vowels preceding target bilabial phonemes were avoided to prevent contamination of data. Sentences were shown to participants in randomized order and the block of 31 sentences read under three conditions was repeated twice resulting in a total of 186 sentences read aloud.

Figure 1: Production of /p/ under neutral, smile and laugh (clockwise from upper left) conditions.

Video data were coded categorically noting whether a sound (b/p/m/f/v/w) was labiodentalized (yes/no) and under which smile condition (neutral/smile/laugh). Chi-squared tests were used to determine which facial condition most often accompanied labiodentalization and which target sounds were most commonly labiodentalized. Variables were aggregated into two contingency tables for yes/no vs. state and yes/no vs. consonant and chi-squared contingency tests were performed on each table using the Python scipy.stats package.

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3 Results

As Figure 2 illustrates, frequency of labiodentalization vary significantly depending on the different facial contexts the phoneme was produced. As predicted, the laugh condition where stress on articulators was greatest generated the highest frequency of labialized bilabial sounds. The chi-square value for this table was 28.93 ($p < .0001$).

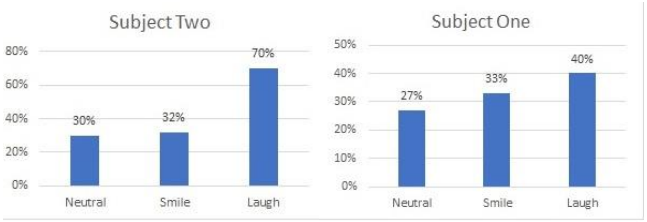

Figure 2: Instances of labiodentalization under varying conditions. Results indicate that the laugh condition exhibited the highest frequency of labiodentalization.

To test whether bilabial sounds with higher levels of muscle activation are less likely to be labiodentalized, another chi-squared test was run examining the labiodentalization variation between the six target phonemes /b/, /p/, /m/, /f/, /v/, and /w/. As figure 3 shows, labiodentalization for /p/ proved to be drastically lower than that of /b/ or /m/.

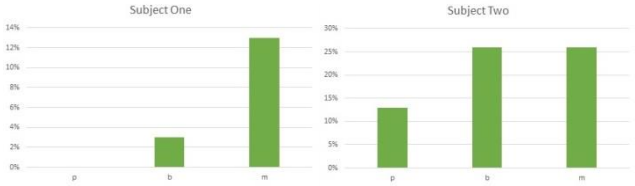

Figure 3: Instances of labialized phonemes for different sounds for subject one and two

4 Discussion

Results from this pilot study indicate that (1) labiodentalization of bilabial stops varies depending on level of conflicting demand from degree of smile and (2) the degree of intraoral pressure of the target sound negatively)influences the likelihood of the sound becoming labiodentalized. While labiodentalization was most likely to occur during the laughing condition where demands on articulators was greatest, there exists substantial variation with percentages of conventional articulation for consonants in neutral and smile conditions to exceed likelihood of labiodentalization. Also as predicted, stop sounds adjacent to labiodental are most likely to be labiodentalized.

5 Conclusion

The present study tested the prediction that bilabial stop consonants such as /m/ with lower intra-oral pressure, and hence lower muscle activation, are more frequently labiodentalized than bilabials with higher activation levels such as /p/ when produced while smiling or laughing. In addition, varying degrees of smile or laugh (and hence degrees of muscle activation) results in increased instances of labiodentalization.

This pilot study adds to the literature on articulatory conflict revealing embodied coarticulatory mechanisms. Future studies will replicate this experiment with a larger number of participants in addition to measuring degrees of closure during sentence production to quantify degrees of labialized bilabial sounds, and will include electromyographic muscle activation results.

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