Effects of Midline Tongue Piercing on Spectral Centroid Frequencies of Sibilants

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Abstract

Compensatory speech motor patterns occur in response to sensory changes in the vocal tract to facilitate natural sounding speech. The purpose of this project was to investigate speech compensation to midline lingual piercing. In the first experiment, two groups of female speakers (one with tongue piercing) produced two sets of speech samples. Tongue piercing barbells were kept in place as baseline for the first set, and removed for the second. No differences between subject groups were found for /s/ spectral centroid frequencies for the baseline set. A progressive change of /s/ centroid frequencies after barbell removal was observed, indicating rapid compensation to the lingual perturbation. In a second experiment speech samples were recorded from three subjects immediately prior to and following tongue piercing. Changes in centroid frequencies of /s/ and /ʃ/ were dependent on the speaker. It is likely that physiological factors contributed to altered speech observed following piercing.

Index Terms: speech compensation, speech perturbation, tongue piercing, centroid frequency, sibilant

1. Introduction

Compensatory speech motor patterns occur in response to sensory changes in the vocal tract to facilitate the most natural speech possible. Without compensatory movement, any physical change to the vocal tract may potentially lead to disordered vocal resonances or articulation [1, 2]. Compensatory articulation has been shown to preferentially preserve areas of constriction along the vocal tract and acoustic features most essential for phoneme identification [3, 4]. Within anatomical limitations, compensation may be determined largely by an internal representation of an ideal acoustic signal [5]. Little is known about the degree of compensation possible in modified conditions and the mechanisms for adaptation.

Compensation of the speech mechanism after the placement of a prosthetic device, such as an artificial palate, is frequently studied. While exposure to new experimental conditions has been reliably shown to induce a compensatory process, the potential of compensatory processes during recalibration to known conditions has received only minimal attention. Baum and McFarland [6] unexpectedly found short-lived residual changes in articulation after the removal of palatal prostheses worn for one hour of repetition tasks interspersed with passage reading tasks heavily laced with /s/. Successive repetitions after the removal of the prosthesis progressed from approximating perturbed speech to approximating unperturbed speech. This finding is preliminary evidence that compensatory processes can be found during recalibration, and that compensation is not immediate.

In Hamlet et al [7], one of the few longitudinal studies of speech compensation, subjects wore an artificial palate with a selectively thickened and retracted alveolar ridge for two weeks and developed compensatory patterns that were retained in memory and returned upon later exposure to the same perturbation. Significantly, subjects' self-reports showed that perceptual speech differences noticed by friends and family nearly dissipated within the first week. In the same study was a single subject who participated in a study one year prior [8] with the same artificial palate. This subject rapidly adopted the same type of compensatory strategies seen previously, suggesting that compensatory patterns can be retained over long periods of time.

Tongue piercings can be considered artificial modifications of the oral cavity in which a prosthetic barbell (jewelry) penetrates the tongue, positioning superior and inferior beads on the respective lingual surfaces (Figure 1). There have been no studies investigating how tongue piercings affect speech production. Anecdotal reports suggest the occurrence of speech difficulties following tongue piercing resolve within two weeks [9, 10], implying a process of speech compensation to the perturbation similar to those described experimentally. Because tongue piercing jewelry is typically worn continuously, the investigation of existing oral body piercings may be an efficient method of studying long-term speech compensation to perturbation without requiring subjects to wear a new experimental prosthesis.

Figure 1: *Photograph of a 5/8", 14g lingual barbell.*

2. Experiment One

2.1. Methodology

Thirteen females who had single midline tongue piercings for at least 6 months and 12 female control subjects with no oral piercings participated in this study. All subjects were native English speakers, 18 or older, and presented with perceptually normal speech. Two pierced subjects reported a history of speech therapy in early childhood. No other speech disorders were reported. The University of Colorado Human Research Committee approved this study, and informed consent was obtained from each participant.

The nature of piercings and barbells could not be controlled because volunteer subjects with pre-existing tongue piercings participated. Barbell shaft diameters included 14 gauge (n=10), 16 gauge (n=2), and 10 gauge (n=1) (measurements based on American Wire Gauge sizing system). Barbell shaft lengths included 5/8” (n=11) and 3/4” (n=2). Mean superior bead diameter was 0.29in (*SD*=0.03 in). Piercings were located at midline of the tongue, anterior to the lingual frenulum, with the superior end of the barbell tilted posteriorly (Figure 2). The superior bead likely occupied a portion of the lingual groove requisite for /s/ production. As measured in 9 subjects, mean tongue tip-barbell distance was 1.85 cm (*SD*=0.17 cm).

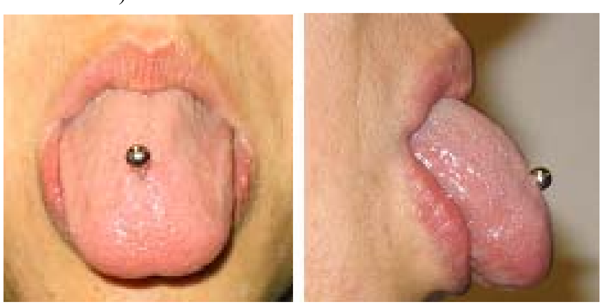

Figure 2: *Superior and lateral photographs of typical barbell placement in single midline tongue piercing showing the superior bead.*

Two 2.5 minute speech samples (recording sessions) were taken over a 10 min span. The sentence “Put the seatbelt on” was repeated throughout each recording session. Pierced subjects kept their barbells in place during the first recording session as a baseline (barbell IN session). It was assumed that speech motor adaptation to the barbell was complete, and that subjects were fully accustomed to speaking with the barbell present. A timed, 5 min break was given between recording sessions, during which pierced subjects removed their barbell for the second recording session (barbell OUT session). Using this sequence of conditions, the oral environment was modified to approximate the environment that existed prior to piercing.

Central 40 msec sections of the first 20 /s/ productions were extracted and analyzed from the productions of “seatbelt.” The first central spectral moment, centroid frequency, was calculated from the power spectrum for each /s/ section using Praat software (version 4.3.27).

2.2. Results

A two-way ANOVA by subject group and recording session revealed no significant differences for centroid frequency [Groups: $F(1)=0.06$, p=0.812; Recording Session: $F(1)=0.03$, p=0.863]. In order to explore compensation patterns upon removal of the lingual barbell, relative centroid frequencies (C_R) by production were calculated for pierced subjects (frequencies are relative to the first production in the recording session). For the barbell IN recording session, no pattern was evident from the first to the last production (Figure 3), as a linear fit for C_R by production number (P) did not explain a significant amount of the variance [R^2(adj)=9.4%, $p>0.05$] (Equation 1).

$$C_R(\%)=99.22-0.771*P \quad (1)$$

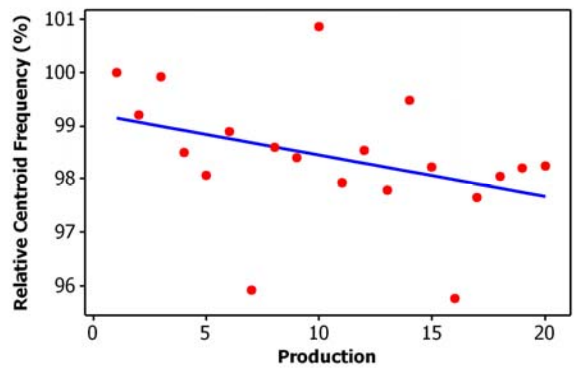

Figure 3: *Barbell IN recording session: Linear fit on mean relative centroid frequency (centroid frequencies plotted as the percentage of the first production).*

For the barbell OUT recording session, a change in the relative centroid frequency of /s/ was observed across the 20 productions (Figure 4). A 3rd order polynomial fit to the relative centroid frequency data accounted for a significant amount of variance [R^2(adj)=51.4%, $p<0.01$] (Equation 2, where P is the production number).

$$CR(\%) = 103.0 - 2.637*P + 0.2127*P^2 - 0.00468*P^3 \quad (2)$$

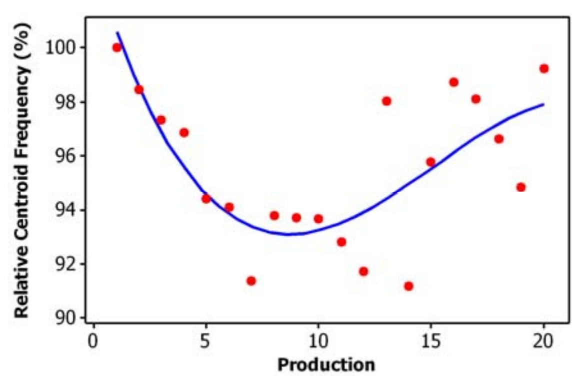

Figure 4: *Barbell OUT recording session: Cubic fit on mean relative centroid frequency (centroid frequencies plotted as the percentage of the first production).*

2.3. Discussion

Although anecdotal reports suggest perceptually identifiable speech differences may dissipate within two weeks of tongue piercing, we predicted that acoustic measures would identify significant differences after long-term tongue piercing. However, such differences between groups were not found for /s/ centroid frequency, suggesting that the pierced subjects were able to compensate for the presence of the barbell by maintaining /s/ centroid frequency within a normal range.

A compensatory process following the removal of the barbell in the pierced subjects (approximating the pre-pierced oral environment) was observed. This process was rapid but not immediate, and appeared to follow a U-shaped pattern. Immediate compensation, indicating instantaneous and complete reactivation of previously established motor patterns (prior to piercing) following barbell removal was not found. Instead, adaptation to the "new" oral environment (barbell OUT) appears to follow a time course likely dependent on experience (repeated productions).

3. Experiment Two

3.1. Methodology

One adult male and two adult female subjects who were planning on obtaining lingual piercing participated in a longitudinal study to assess changes in speech during the initial post-piercing period. All subjects were native English speakers with perceptually normal speech production at baseline. Subject L1 was a 22 year old female with no other oral piercings. Subject L2 was a 23 year old male with a childhood history of speech therapy and 2 piercings in his lower lip left of the midline. Subject L3 was a 20 year old female with no other oral piercings and was a native speaker of English and Hmong.

Eleven speech samples were scheduled to be taken from each subject. Three baseline samples were taken on separate days. Samples were taken every-other day for the first two weeks post-piercing, beginning with the first day after the piercing, and at a follow-up 6 weeks post-piercing. It was assumed that speech compensation to the barbell would be completed within 6 weeks. Efforts were made to schedule all appointments at approximately the same time of day. Subject L1 withdrew prior to completion, yielding 11 samples.

At each session, five repetitions of each target phoneme before the high vowel /i/ were elicited by asking subjects to read carrier sentences aloud. Centroid frequencies from each production of the target sibilants /s/ and /ʃ/ were calculated as described in Experiment 1. A criterion reference for indications of change was set relative to baseline to ensure that criteria for changes were standardized across measures. A change in centroid frequency was assumed if mean values differed from the baseline by twice the baseline standard deviation (Equation 3, where P is the mean for a single post-piercing session, B is the array of means from all three baseline sessions, and SD_B is the standard deviation of B.

$$\left|\bar{B} - P\right| \geq 2SD_B \tag{3}$$

3.2. Results

Lower mean /s/ centroid frequencies of /s/ were indicated on Day 1 for Subject L1, on Day 3 for Subject L2, and until Day 5 for Subject L3 (Figure 5). Mean /s/ centroid frequencies for Subject L1 were variable across post-piercing sessions, including means that were both above and below the baseline range. In the majority of the post-piercing sessions, higher variability (greater standard deviations relative to baseline sessions) was observed for all subjects.

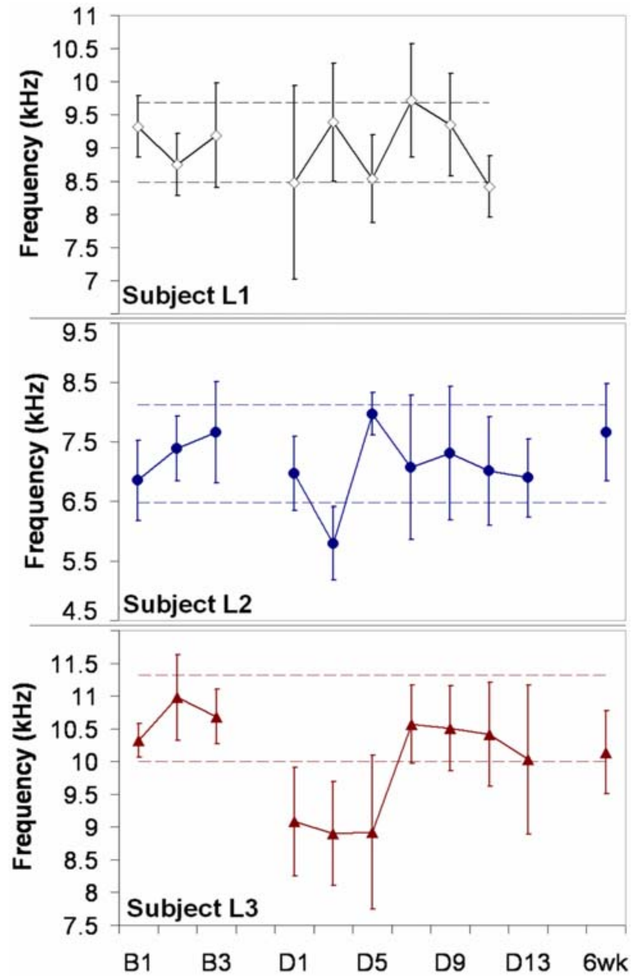

Figure 5: *Mean centroid frequencies of /s/ by session before and after tongue piercing. Error bars show 1 SD from the mean for each session. Dashed lines show 2 SD from the mean of the three baseline sessions as a "normal" baseline range. Sessions (X-axis) are labeled as follows: B# = Baseline session #, D# =Days since piercing, 6wk = 6 week follow-up.*

Higher mean /ʃ/ centroid frequencies were observed for two subjects following piercing (Figure 6). Higher mean /ʃ/ centroid frequencies were indicated until Day 13 for subjects L2 and L3. However, this pattern was not seen in Subject L1. A lower mean /ʃ/ centroid frequency was observed on Day 1 for subject L1, opposite of the change in frequency observed for subjects L2 and L3.

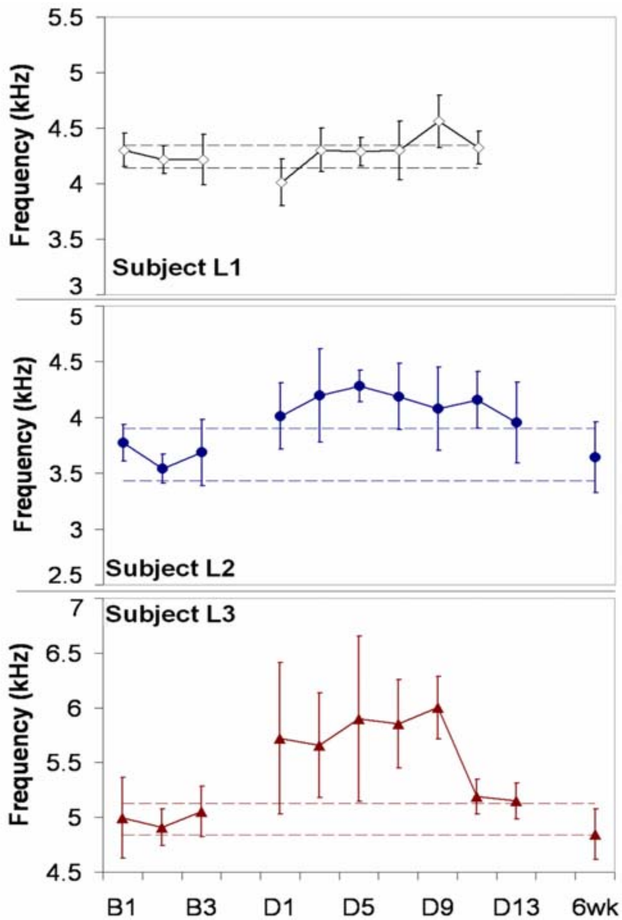

Figure 6: Mean centroid frequencies of /ʃ/ by session before and after tongue piercing. Parameters of these graphs are the same as those described in Figure 5.

3.3. Discussion

Changes in centroid frequencies of /s/ and /ʃ/ immediately following tongue piercing were unpredictable and dependent on the individual speaker. Lingual range of motion was reduced until day 11, and self-reported pain levels peaked within the first 3 days post-piercing, reducing sharply after that. It is likely the dramatic changes in fricative centroid frequencies is due to these physiological factors in conjunction with experience-driven learning.

4. Conclusions

For experiment 1, a compensatory process following the removal of the barbell in the pierced subjects (approximating the pre-pierced oral environment) was observed. This process was rapid but not immediate, and appeared to follow a U-shaped pattern. This curvilinear function suggests that subjects responded to the altered oral environment by changing their lingual motor patterns, likely due to acoustic, somatosensory or a combination of these feedback mechanisms. Immediate compensation, indicating instantaneous and complete reactivation of previously established motor patterns (prior to piercing) following barbell removal was not found. Instead, adaptation to the “new” oral environment (barbell OUT) appears to follow a time course likely dependent on experience (repeated productions).

Changes in centroid frequencies of /s/ and /ʃ/ immediately following tongue piercing were unpredictable and dependent on the individual speaker. It is likely that physiological factors such as pain, inflammation, and reduced lingual range of motion contributed to altered speech observed following piercing.

Physiological measures, such as lingual kinematics or lingual EMG, may reveal details of compensatory movements not identified by the current acoustic analysis.

5. Acknowledgements

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6. References

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