Behavioral and Neurophysiological Correlates of Vocal Motor Learning During Altered Auditory Feedback

Victoria Rogers, Chantel Juitt, Stacey Sangtian, Roozbeh Behroozmand

Speech Neuroscience Lab, Department of Communication Sciences and Disorders, University of South Carolina

*Authors VR, CJ, and SS have equally contributed to this research work.

SPEECH NEUROSCIENCE LAB

UNIVERSITY OF SOUTH CAROLINA

INTRODUCTION

Background:

Auditory feedback aids in the control of speech production by allowing an individual to audibly listen to, process, and adjust his own speech[1]. When an individual receives auditory feedback that involves a pitch-shift (lowered or raised), an audible change in pitch is perceived[2,3]. Repeated exposure to pitch-shifted auditory feedback results in vocal motor learning, a process by which speakers produce speech adaptation responses that compensate for perceived pitch changes[4].

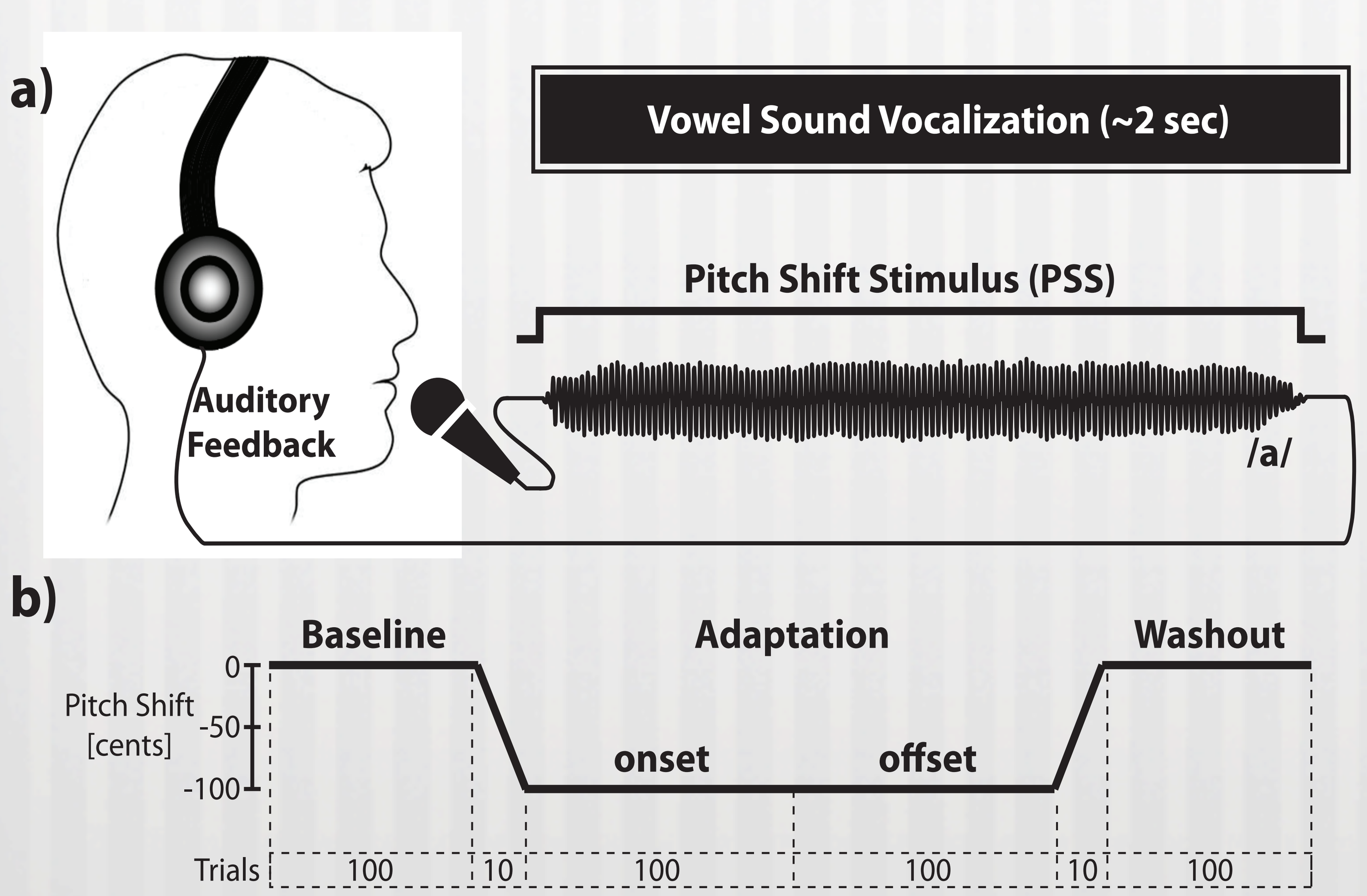
The behavioral correlates of vocal motor learning have been investigated in previous studies by showing that speakers compensate for pitch-shifts in the auditory feedback by changing the pitch of their voice in the opposite direction to the stimulus[4,5,6]. However, the underlying neural mechanisms of vocal motor learning in response to altered auditory feedback remains unknown.

Objective:

The present study aims to investigate the neural mechanisms of vocal motor learning by incorporating the use of electroencephalography (EEG) to obtain ERP responses to pitch-shifted auditory feedback during phonation of a steady vowel sound.

METHOD

13 healthy subjects (1 male, 12 female) repeatedly produced steady vocalizations of the vowel sound /a/ while receiving voice auditory feedback across four vocalization phases. **1) Baseline** in which the voice auditory feedback was not altered. **2) Adaptation (onset)** during which auditory feedback was shifted down by a -100 cents stimulus. **3) Adaptation (offset)** which was the continuation of the previous adaptation phase. **4) Washout** during which the subject's auditory feedback was returned to pre-adaptation baseline (no alteration).



RESULTS: BEHAVIORAL DATA

Behavioral vocal responses to pitch shift stimuli:

In response to the altered auditory feedback, subjects compensated for the downward pitch shifts with an upward pitch shift in their vocalizations (See Figure 1). The upward pitch shift in subjects' vocalizations continued to increase between the onset and offset of the adaptation period. However, the increase in pitch was maintained throughout the washout period.

RESULTS: EEG DATA

Analysis of EEG data identified two major event-related potential (ERP) components that reflect the mechanism involved in the motor planning and production of vocalizations. The first significant ERP component occurred -150 ms prior to the onset of vocalization and presented as a positive peak response. The second major component occurred 300 ms following the onset of vocalization and presented as a negative peak response (See Figure 2a).

Motor Planning:

Topographical distribution of ERP responses (See Figure 2b) revealed a positivity that occurred predominantly in the left pre-frontal hemisphere during motor planning. When presented with novel auditory feedback (during the adaptation onset and washout phases), this positive response was suppressed.

Vocal Production:

Both auditory and motor components were involved in vocal production (See Figure 2b), as evidenced by bilateral positive temporal activity and negative fronto-parietal activity. A strong modulation in positive activity between phases was observed in the parietal cortex (See Figure 3c) during vocal production, similar to the left pre-frontal responses during motor planning (Figure 3a). Frontal and fronto-central positive responses increased when presented with novel stimuli during the adaptation onset phase (See Figure 3c).

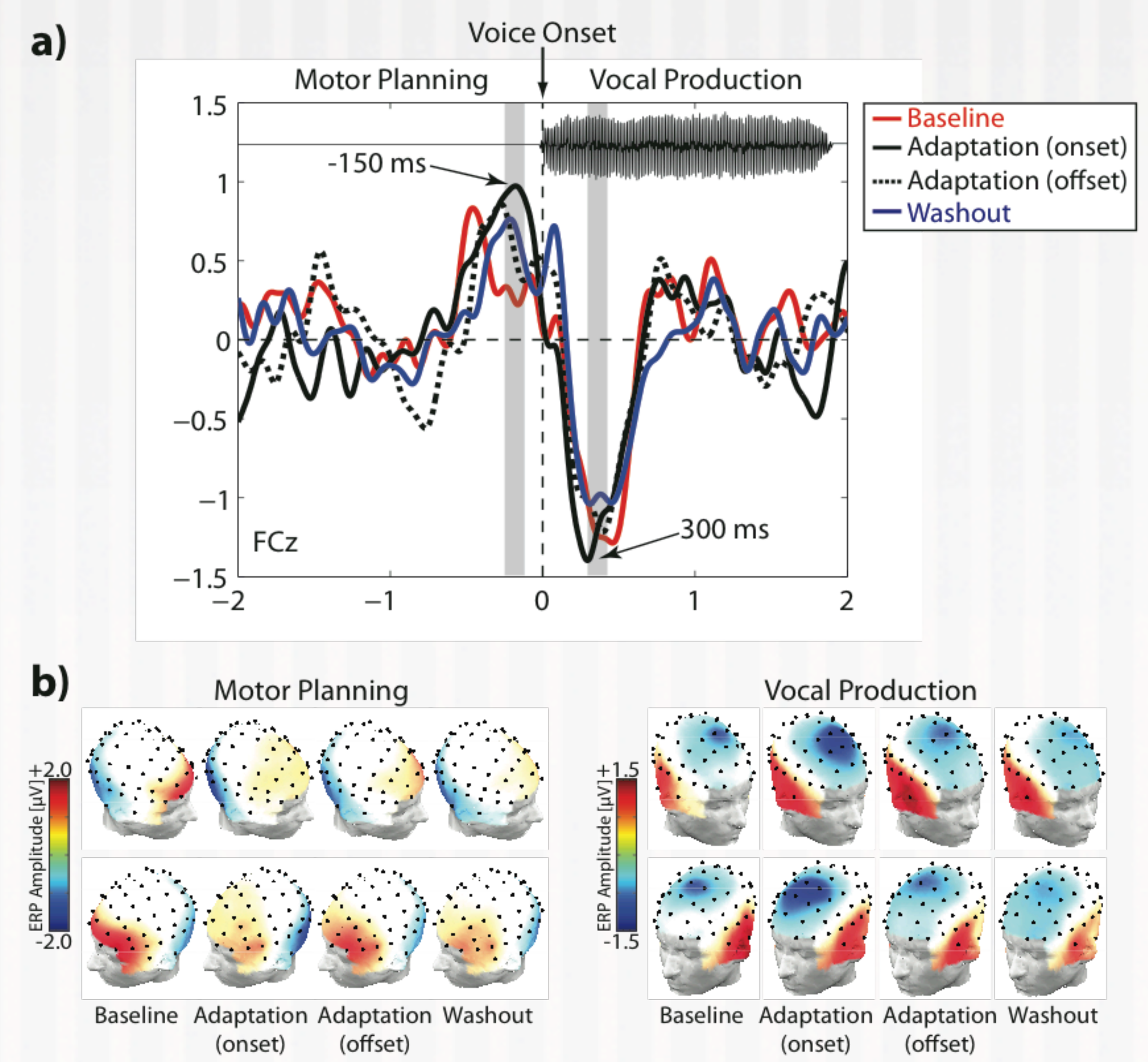


Figure 2. a) Overlaid ERP responses of channel FCz for four phases: baseline, adaptation onset, adaptation offset, and washout. b) The topographical distribution maps of the scalp-recorded ERPs in response to downward pitch shift stimuli during motor planning and vocal production.

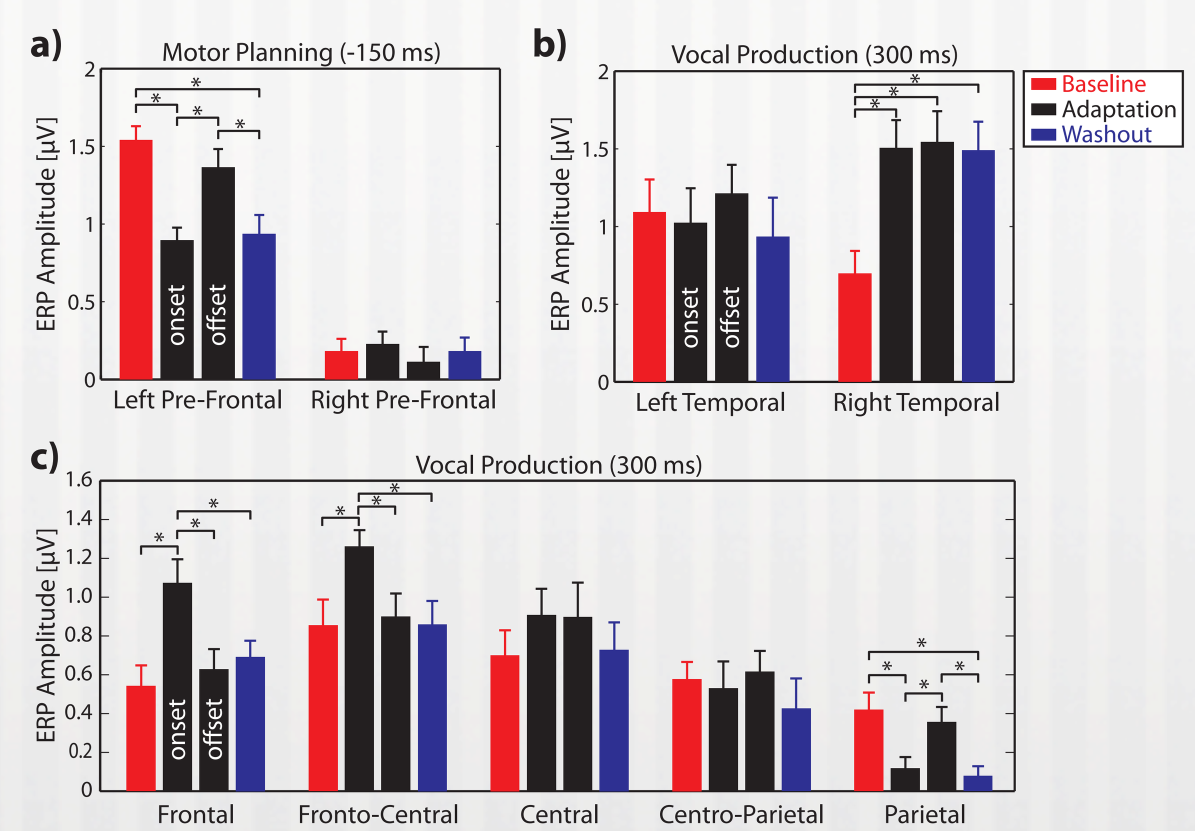


Figure 3. a) Bar plot representation comparing left pre-frontal and right prefrontal ERP amplitudes during motor planning across baseline, adaptation, and washout periods. b) Bar plot representation comparing left temporal and right temporal ERP amplitudes during vocal production across baseline, adaptation, and washout periods. c) Bar plot representation comparing frontal, fronto-central, central, centro-parietal, and parietal ERP amplitudes during vocal production across baseline, adaptation, and washout.

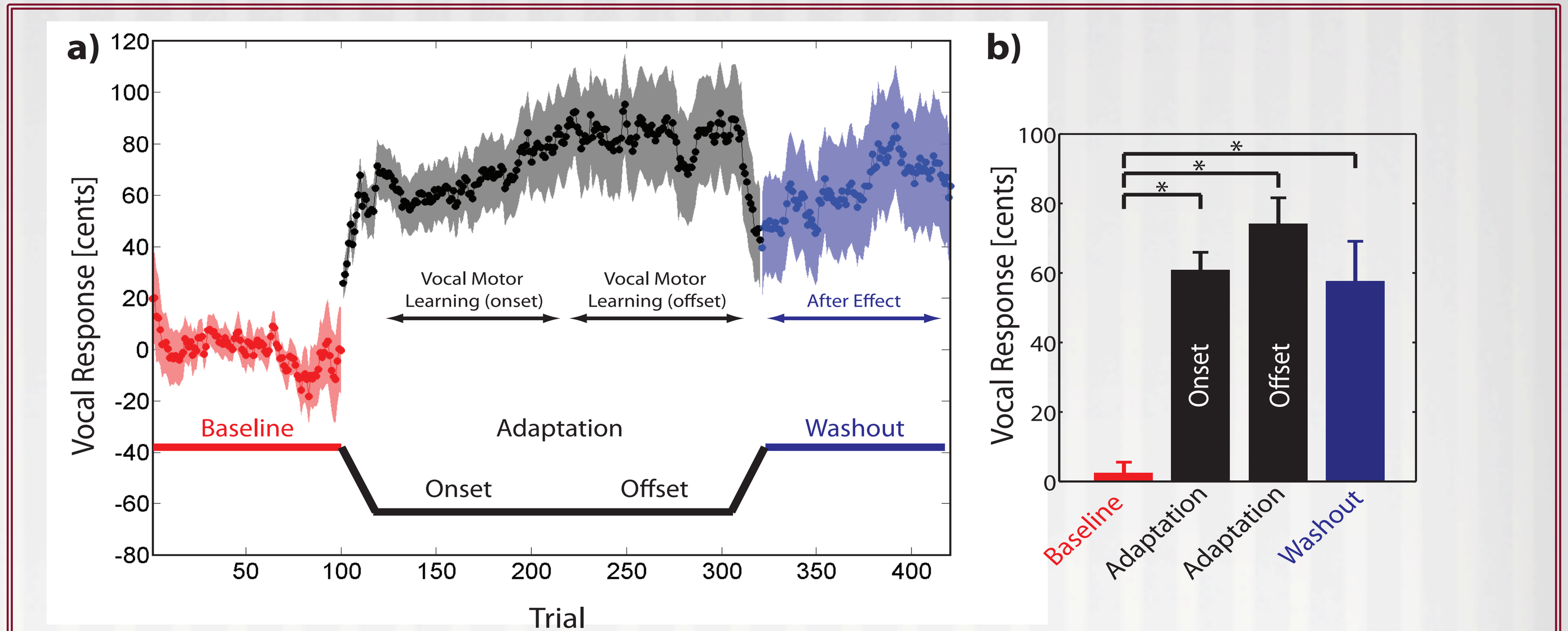


Figure 1. a) Behavioral vocal responses to downward pitch shift auditory feedback across four vocalization phases: baseline, adaptation (onset and offset), and washout. b) bar plot representation comparing vocal responses between each vocalization phase.

DISCUSSION

In this study, we investigated the behavioral and neurophysiological correlates of vocal motor learning in response to downward pitch shift stimuli. Consistent with previous studies, we found that subjects compensated for downward pitch shifts in auditory feedback with an increase in pitch. This behavioral change was maintained throughout the washout period. Furthermore, we found that suppression of a positive ERP response occurred in the left pre-frontal cortex during adaptation onset and washout, i.e., during periods of the task in which novel stimuli was presented. During vocal production, an increase in neural activity was noted in the right temporal lobe during adaptation and washout in addition to a spike in activity during adaptation onset in the frontal and fronto-central cortices. Interestingly, we also found that modulation patterns of ERP responses in the frontal and parietal lobes correlated throughout the task. Our findings help to elucidate areas of brain involved in motor learning during changes in sensory feedback.

REFERENCES

[1] Keough, D., Hawco, C., Jones, J.A., 2013. Auditory-motor adaptation to frequency-altered auditory feedback occurs when participants ignore feedback. BMC NeuroSci. 14, 25.

[2] Sengupta, R., Nasir, S.M., 2015. Redistribution of neural phase coherence reflects establishment of feedforward map in speech motor adaptation. J Neurophysiol. 113, 7.

[3] Lameti, D.R., Nasir, S.M., Ostry, D.J. 2012. Sensory preference in speech production revealed by simultaneous alteration of auditory and somatosensory feedback. J. Neurosci. 32, 27.

[4] Jones, J.A., Munhall, K.G. 2005. Remapping auditory-motor representations in voice production. Current Biology, 15, 1768-1772.

[5] Jones J.A., Munhall, K.G. 2002. The role of auditory feedback during phonation: Studies of mandarin tone production. Journal of Phonetics, 30, 303-320.

[6] Xu, Y., Larson, C.R., Hain, T.C. 2004. Compensation for pitch shifted auditory feedback during the production of mandarin tone sequences. J Acoust Soc Am, 116, 2, 1168-1178.