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Brain activity during altered auditory feedback: an FMRI study in healthy adolescents

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Objective

Altering auditory feedback to self-generated speech either with respect to time (delayed auditory feedback) or pitch (frequency-shifted feedback) is effective for enhancing fluency in people who stutter. In this study of fluent speakers, we investigated the effects of these two types of altered feedback on patterns of brain activity associated with producing and hearing one's own speech.

Methods

Eight healthy adolescents, aged 14-21 years (mean 17 years; SD 3 years) were scanned at 3T. Functional images, acquired every 10s, comprised 3-s acquisition of 32 4-mm axial slices (in-plane resolution 4mm × 4mm), followed by 7s of silence (96 images, 16mins). During the silence, subjects saw a stimulus that was either a meaningful sentence or a row of Xs and read the sentences aloud. Speech was recorded and fed back to the subjects via a real-time digitizer. Feedback was either (i) normal (ii) delayed by 200ms or (iii) frequency-shifted by half an octave upwards. The functional images were analysed using the FMRIB Software Library. Motion corrected images were registered to the MNI-152 template, smoothed and analysed using the GLM. Statistical maps (cluster threshold at Z>2.3, p=0.05, corrected) were generated to show patterns of activation during each condition separately and in comparison to each other.

Results & Discussion

For the normal, delayed and frequency-shifted feedback conditions significant activation clusters were seen in the left inferior frontal gyrus (IFG) extending to the opercular surface and ventral premotor cortex, bilateral dorsal cingulate gyrus, pre-SMA, sensorimotor cortex (about the level of the face representation), posterior superior temporal gyrus (STG), left thalamus, and superior cerebellum (vermal zone and both hemispheres laterally). The activity in this network is consistent with overt speech production and auditory perception of that production.

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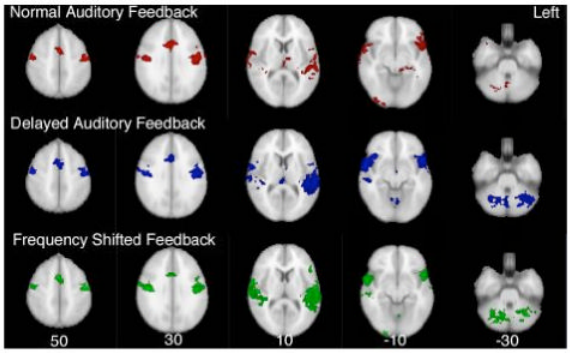
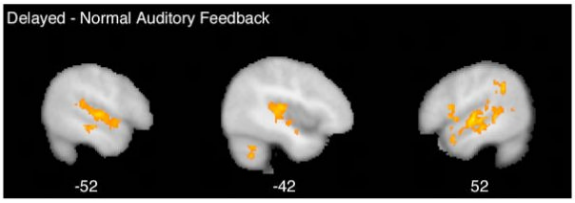


Delayed compared to normal feedback revealed significantly increased activation of the right posterior IFG, STG bilaterally and extensively along its length, right superior temporal sulcus and the left cerebellar hemisphere (posterior and lateral portions).



Frequency-shifted compared to normal feedback showed increased activation of the mid- to posterior STG bilaterally extending to the superior temporal sulcus on the right.

Altered auditory feedback raises awareness of and attention to produced speech. The increased activity, particularly in the right hemisphere, during delayed and frequency-shifted relative to normal feedback is consistent with these influences. Also, in contrast to previous reports (1), significantly increased activation was seen in the cerebellum under delayed compared to normal auditory feedback (for the frequency-shifted feedback condition this activity was sub-threshold). This activity may reflect timing differences in speech production and perception under altered feedback (10-15% increased duration of sentences).

Conclusions

Altered feedback increases activity in posterior STG and cerebellum. These changes may underlie the fluency-enhancing benefits of altered feedback in people who stutter.

Acknowledgments

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References

(1). Hashimoto, Sakai. Human Brain Mapp. 2003; 20:22–28.