Noninvasive brain stimulation to facilitate foreign language speech-sound learning in low-aptitude learners

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Results

Learning with Low Aptitude for Pitch Perception

Extensive work has shown that pitch perception abilities constrain the ability to learn a tone language as a second language (Wong & Perrachione, 2007; Bowles, Chang, & Karuzis, 2016).

A. Learners with high pitch-contour perception abilities have better aptitude for learning lexical tones in words.

B. Anodal tDCS stimulation improves lexical tone vocabulary learning in a number of low-aptitude learners.

C. Low-aptitude learners receiving anodal stimulation show greater than expected learning; sham stimulation has no effect.

D. Better generalization to novel talkers after training with anodal stimulation; no group difference in pre-training aptitude.

Acknowledgments

We thank Emily Thurston, Terri Scott, Lauren Gustaonis, Jennifer Golditch, and Deirdre McLaughlin for their assistance.

This work was supported in part by NIH (NIDCD) grant R03 DC014045 and Brain and Behavior Research Foundation grant 23503 to TP. EH was supported in part by an award from the BU Undergraduate Research Opportunities Program.

References

Datta et al. (2009). Brain Stimulation

Villamar et al. (2013). J. Visualized Experiments

The Pitch Contour Perception Test is available online as free, open-source: http://hdl.handle.net/2144/16461

Noninvasive Brain Stimulation

HD-tDCS stimulation location and current flow maps

Noninvasive brain stimulation (high-definition transcranial direct current stimulation, HD-tDCS: Datta et al., 2009; Villamar et al., 2013) was applied over left IFG with anodal polarity at 2mA. Participants were randomly assigned to anodal or ‘sham’ stimulation conditions. Anodal stimulation lasted the full course of each training and testing session (~15-20 min). Sham stimulation had the same setup as anodal stimulation. Participants who scored <75% on their pre-training pitch perception abilities were assigned to anodal stimulation; no electric current was delivered during training. Participants were blind to their stimulation condition. Locations of stimulating (anodal) and return (cathodal) electrodes and maps of cerebral current flow are shown above. These locations were determined based on neuroimaging work suggesting the importance of left IFG in foreign language learning (Wong, Perrachione, & Parrish, 2007; Myers, 2014, Dayan et al., 2006).

Lexical Tone Vocabulary Training

Pitch Contour Perception Test

The PCPT is a strong predictor of how well adults can learn words with lexical tones like those in Mandarin Chinese (Wong & Perrachione, 2007; Perrachione et al. 2011). Listeners hear isolated vowels with a superimposed pitch contour and, in a 2AFC task, match the pitch they hear to a representative arrow indicating the pitch contour direction (rising, falling, or level). Participants who score >75% on this test successfully learn a tone language vocabulary; those who score lower do not learn the vocabulary.

Participants

Youth aged scoring ≥ 70% on the PCPT (N = 16) with normal speech, language, hearing, and cognitive abilities were assigned to undergo tone-language vocabulary training while receiving anodal tDCS (n = 8) or sham tDCS (n = 8).

Stimuli

Participants learned a vocabulary of 18 words: 6 syllables each superimposed with 3 Mandarin lexical tones (level, rising, falling) spoken by 4 different talkers (2 male, 2 female). Each word (syllable + tone contour) was uniquely associated with a photograph of an object.

Procedure

Training took place in 15-20 minute sessions on 4 consecutive days. (A) Participants were familiarized with the words by hearing each spoken in isolation while the corresponding picture was on the screen. Stimulation was intermixed in minimal triplets by tone. All talkers were intermixed during training in a high-variability design. Participants then practiced identifying the words in each minimal triplet with corrective feedback. (B) Learning progress was measured on a daily word identification test with all 72 tokens (6 syllables × 3 tokens × 4 talkers). After the word identification test on day 4, listeners also completed a generalization test, comprised of the same 18 words spoken by 2 new, untrained talkers.

Lexical tone vocabulary training design

Generalization, Anodal vs. Sham:

- Anodal Group: 43.1% - 85.2% (mean = 64.2%)
- Sham Group: 23.1% - 39.8% (mean = 34.1%)
- two-sample t = 2.21, p < 0.05 *
- Cohen's d = 1.18

No group difference in pre-training PCPT scores.

- Anodal Group: 58% - 70% (mean = 64.8%)
- Sham Group: 58% - 69% (mean = 65.1%)
- two-sample t = 0.18, p = 0.86

Correlation between Accuracy and PCPT scores:

- Anodal Group: Spearman's rho = 0.16, p = 0.64
- Sham Group: Spearman's rho = 0.69, p = 0.06

Summary

- Pitch-contour perception predicts the ability to learn to use lexical tones.
- English-speakers with low pitch-contour perception abilities learned a vocabulary incorporating lexical tone minimal contrasts.
- Participants received either anodal transcranial direct current stimulation (tDCS) or sham stimulation during training.
- Active brain stimulation improved learning for some low-aptitude learners, who performed as well as high-aptitude learners.
- Sham stimulation did not improve learning in low-aptitude learners.
- Noninvasive brain stimulation may help recover speech-sound learning abilities in listeners with low pre-training perceptual aptitudes.