Using neuroimaging to investigate persistent developmental stuttering

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Abstract

Persistent developmental stuttering, a disorder affecting approximately 1% of adults in the world, is characterized by disfluencies in speech production. Using the “CONN” Functional Connectivity Toolbox, the present study analyzes functional magnetic resonance imaging (fMRI) images for stuttering and nonstuttering subjects, in order to identify the resting-state functional connectivity (FC) differences between stutterers (PWS) and nonstutterers (PNS), the correlations between FC and stuttering severity, as well as the FC differences between rhythmic and normal behavioral conditions, to better understand the rhythm effect in stuttering. We found that, compared to PNS, PWS had stronger FC between the left planum temporale and the right orbitofrontal cortex and left putamen, as well as between left cerebellum lobule 6 and both right posterior superior temporal gyrus and right ventral inferior frontal gyrus pars opercularis (IFo). PWS were found to have weaker FC than PNS between left pre-supplementary motor area (pre-SMA) and the right thalamus, likely reflecting a deficit within the cortico-basal-ganglia planning loop. In addition, we found a negative correlation between stuttering severity and FC between left pre-SMA and bilateral motor and somatosensory cortex, and a positive correlation between severity and FC between right dorsal IFO and left cerebellar regions. This suggests that right IFO and cerebellum may increasingly take over for the dysfunctional left hemispheric speech-motor planning network as stuttering severity increases. Moreover, we found evidence indicating that rhythm induces fluency, possibly eliminating the need for right frontal and cerebellar compensation, and that rhythm may normalize deficits in speech initiation/termination in PWS.

Results & Discussion

1. Results indicate that PWS likely excessively rely on auditory feedback as a form of compensation for their dysfunctional left hemispheric speech networks.
2. This increase in FC in right orbitofrontal (result #1), auditory and cerebellar areas support Kell et al.’s findings, and may indicate attempted compensation in PWS.
3. Suggests the role of the R. IFO and cerebellum in taking over a greater load to compensate for LH speech network deficits.
4. Likely represents a deficit in the speech planning aspect of the cortico-BG planning loop in PWS.

Group Differences in FC:

1. As severity increases, there is a greater dissociation between speech planning and speech-motor execution areas.
2. Suggests a disconnect between breathing and articulation components in PWS.
3. Indicates the right IFO and cerebellum taking over a greater speech production load to compensate.

FC Correlations with Stuttering Severity:

1. Results from #4 & #5 indicate a negative correlation to the motor and somatosensory cortices for number of disfluencies in the Normal condition, but no correlation for number of disfluencies in the rhythmic condition. This may suggest that the Rhythmic condition normalizes FC between the BG and motor/somatosensory cortex, thus temporally inducing normalized speech initiation and execution timing in PWS.

Conclusions

• Overall, we found increased FC from left hemispheric speech-motor areas to the left cerebellum lobule 6, right orbitofrontal cortex, and right IFO in PWS compared to PNS, and a positive correlation between stuttering severity and FC between the right IFO and bilateral cerebellum.
• These results solidify the role of right frontal and cerebellar regions taking a greater speech planning/production load in PWS, to compensate for a dysfunctional left hemispheric speech-motor planning network.
• In addition, in a comparison between number of disfluencies in normal vs. rhythmic conditions, we found evidence indicating that rhythm may eliminate the need for right frontal and cerebellar compensation in PWS, perhaps because rhythm has temporally normalized the left hemispheric speech network deficits.
• We found evidence suggesting that the presence of rhythm can also normalize the timing of speech initiation and termination in PWS, perhaps by normalizing FC between the BG and motor/somatosensory cortex.

Methods

• A total of 21 healthy participants were selected for the experimental component of the study, in which there were 2 conditions—rhythmic and normal.
• The sentence “The steady bat gave birth to pups” was read by each subject 216 times total, 108 times per condition.
• An auditory metronome stimuli sounded before each trial.
• Automatic Speech Recognition (ASR) objectively evaluated how well each subject aligned their speech units to the metronome beats
• CONN toolbox was used to preprocess and analyze fMRI data for 21 subjects.
• In second-level analysis, group comparisons were performed to compare regional connectivity strength.
• All results used a voxel-wise threshold of p<0.001, and cluster-corrected p<0.05
• SISI-4 scores, the number of disfluencies in the rhythmic and normal conditions, and deceleration times were used as 2nd, level covariates in ConN to measure correlations between the covariance and relative regional connectivity strength.

• Results from #1, #2, and #3 indicate that the right orbitofrontal cortex and right cerebellum lobule 6 were recruited for compensation in the Normal condition (positive correlation for number of disfluencies in normal condition), but its compensatory role was no longer needed during the Rhythmic condition as fluency improved (no correlation for number of disfluencies in rhythmic condition)

References


Acknowledgments

This work was supported through an NIH Grant, and I would like to thank Dr. Guenther, Dr. Tourville, Saul Frankford, and the lab as a whole for assisting me throughout the project.