Domain-Specific Neural Profiles of Statistical Learning of Speech and Tone in Young Children

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Background

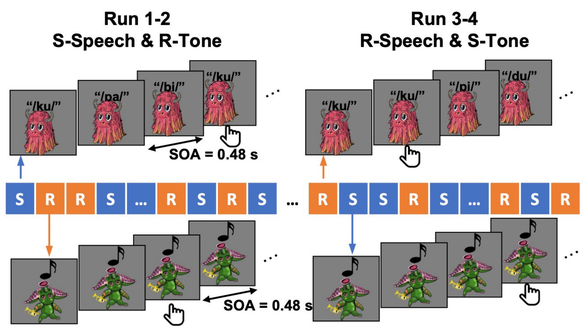
- Statistical learning (SL) is the ability to extract regularities from the environment, and is thought to improve throughout childhood (Arnon, 2019)
- Although SL is typically considered a domain-general mechanism of learning (e.g., Palmer et al., 2016), recent research has proposed that SL is constrained by domain-specific properties (Frost et al., 2015) in the adult brain.
- Whether SL is domain-general or constrained by domain-specific properties in the developing brain remains an open question

Research Question

Which brain regions functionally support SL across domains in children ages 5-7 years?

Method

- Thirty children ages 5-7 years (*M*age = 6.45 years, *SD*age = 1.05) were exposed to sequences of structured and random syllables or tones (Schneider et al., 2020).
- For structured sequences, syllables and tones were concatenated into triplets with the transitional probability as 1 for neighboring syllables/tones within triplets and as 0.33 for cross-triplets.
- No temporal transitional regularity in random sequences.
- Children were pseudo-randomly assigned to track a target syllable or tone, and were instructed to press a button when they heard this target syllable/tone.



Analysis & Results

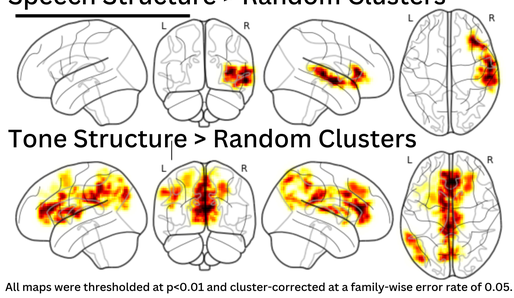
Behavioral Reaction Time (RT)

Mean reaction time was faster during processing of structured versus random sequences across both domains.

	Structured	Random	*t*	*p*
Speech	192.33 (394.20)	444.68 (168.74)	-4.51	<.001
Tone	106.51 (371.75)	363.38 (129.40)	-3.34	.004

Univariate group-averaged results indicate distinct regions of activation across domains during SL

Speech Structure > Random Clusters



Tone Structure > Random Clusters

All maps were thresholded at p<0.01 and cluster-corrected at a family-wise error rate of 0.05.

Processing of speech structured > random sequences activated the right Superior Temporal Gyrus (STG).

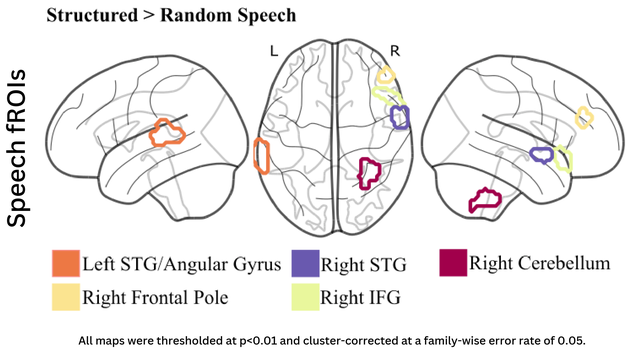
Processing of tone structured > random sequences engaged the left Milddle Frontal Gyrus (MFG), left Angular Gyrus (AG), bilateral Superior Frontal Gyrus (SFG), and Cingulate Gyrus (CG).

Conjunction analyses failed to identify any brain region activated across tasks.

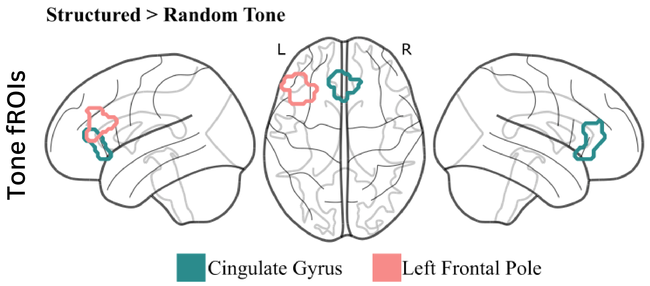
SL activates distinct fROIs in individual brains across domains

Group-constrained subject-specific (GCSS; Scott & Perrachione, 2019)

GCSS analyses were used to identify individual-subject functional regions of interest (fROIs) in our sample. A set of fROIs were extracted for structure versus random contrasts among 60% or more of children in both the speech and tone tasks.



All maps were thresholded at p<0.01 and cluster-corrected at a family-wise error rate of 0.05.

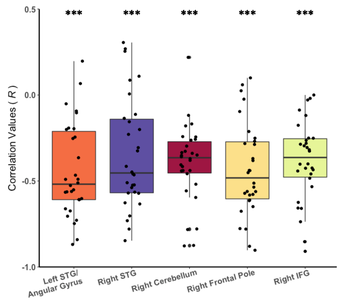


Conjunction analyses showed no overlap between speech and tone fROIs.

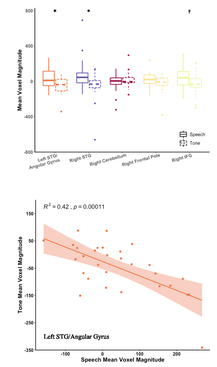
Negative cross-task correlations suggest SL is constrained by domain-specific properties in the developing brain

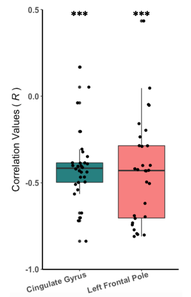
Local Pattern Similiarity Analysis (Scott & Perrachione, 2019)

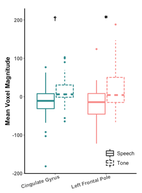
To determine whether the patterns of activation elicited by each task were similar across tasks in individual brains, we performed a multi-voxel pattern analysis within fROIs.

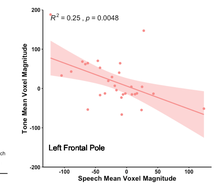


Cross-tasks correlations within speech and tone fROIs significantly differed from zero.









These cross-task correlations indicate domain-specific fROIs are active for SL within that domain, but suppressed during SL across domains.

A whole-brain LPSA failed to identify any fROI where patterns of activation were similar across tasks in individual subjects

Conclusions & Discussions

- Consistent with previous research, temporal and frontal regions were involved in auditory SL across both linguistic and non-linguistic domains (McNealy et al., 2006; 2010); however, there was a lack of spatial convergence across domains.
  - Linguistic SL activated right temporal regions thought to support the extraction and encoding of temporal statistics of speech in the developing brain (Leonard et al., 2015)
  - Non-linguistic SL activated portions of the default mode network (DMN), which may facilitate the generation of automated predictions about the environment by incorporating experience-derived building blocks of world regularities into ongoing predictions (Dohmatob et al., 2020)
- Cross-task correlations indicated that fROIS specific to speech were only highly activated for learning linguistic, but not non-linguistic regularities, and vice versa. This task-induced deactivation across domains during SL may occur in brain regions irrelevant to SL in the opposite domain in a manner that boosts neural processing efficiency and benefits task performance.
- Taken together, we provide evidence that, similar to Frost et al. (2015), auditory SL is constrained by domain-specific properties in the developing brain.

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