Reduced phonological working memory in autism is associated with altered speech-motor engagement

Amanda M. O'Brien[1,2], Tyler K. Perrachione[3], Helen Tager-Flusberg[3], John D. E. Gabrieli[2], Zhenghan Qi[2, 4]

[1]Harvard University, [2]Massachusetts Institute of Technology, [3]Boston University, [4]Northeastern University

Introduction

Nonword repetition (NWR) is a standard clinical measure for phonological working memory (PWM) with **high sensitivity and specificity** for developmental language disorders (Weismer et al., 2000).

NWR involves three processes: **speech perception, working memory, and speech production.**

Research has suggested behavioral and neural differences in children with autism for each of these processes (Tryfon et al., 2018; Habib et al., 2019; Williams et al., 2013; Pang et al., 2015).

In this study, we compare the **neural networks used during NWR** by children with autism to neurotypical controls, and to a group of children with a **reading disability**, to gain novel insight into the unique neural bases of phonological working memory in ASD.

Methods

Participants

		NT N = 28 (8 F)		ASD N = 23 (5F)		ASD < NT	RD N = 16 (7F)		RD < NT	RD < ASD
		Mean	SD	Mean	SD	p-value	Mean	SD	p-value	p-value
Demographics	Age	11.9	3.2	12.2	3.4	0.389	11.5	3.1	0.345	0.266
	KBIT (IQ)	112.8	14.2	110.6	16.2	0.302	104.3	12.3	**0.022**	0.088
Language	CELF (CLS)	116.2	9.8	103.2	19.2	**0.004**	97.3	17.9	**0.001**	0.166
NWR	In-scanner NWR	87.7	8.8	75.0	22.7	**0.000**	73.8	21.2	**0.000**	0.262
	CTOPP (NWR)	10.0	2.7	7.7	2.1	**0.001**	8.4	2.7	**0.035**	0.199
	CNRep (Raw)	34.7	3.2	30.1	6.4	**0.002**	30	6.2	**0.005**	0.475
Reading	TOWRE (SWE)	108.3	9.9	97.5	10.5	**0.001**	83.1	7.2	**0.000**	**0.000**
	TOWRE (PDE)	110.3	13.3	101.7	12.4	**0.012**	83.7	5.0	**0.000**	**0.000**

Table 1. Phenotypic cognitive, behavioral, language, and reading scores in autistic (ASD), neurotypical (NT) and the reading disability (RD) groups. *p*-values are from one-tailed t-tests.

Experimental Session

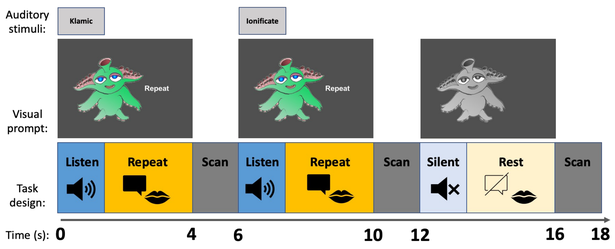

Figure 1. Task design and accompanying visual prompt. The task was conducted in three runs. Each run included 32 trials, including 8 trials of each syllable load (two, three, four, five syllables) and 8 trials of rest.

Stimuli: 96 nonwords, phonetically matched to English, in four PWM loads (2, 3, 4, 5-syllables), previously validated in Perrachione et al. (2017).

Scanning: Siemens Trio 3T MRI scanner, 32-channel head coil. TR = 6s, TA = 2s, sparse sampling, FOV 192mm^2, voxel resolution = 3 mm^3, flip angle 90 degrees.

Analyses

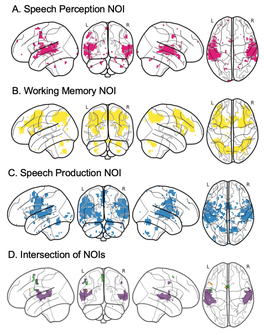

Figure 2. Networks of interest (NOI) derived from Neurosynth.org used for the univariate and multivariate analyses.

fMRIPrep used for Preprocessing; **SnPM** was used for non-parametric univariate analyses; **PyMVPA** bids app used for neural decoding.

Results

The autism and reading disability groups performed worse on the in-scanner NWR task than the NT group.

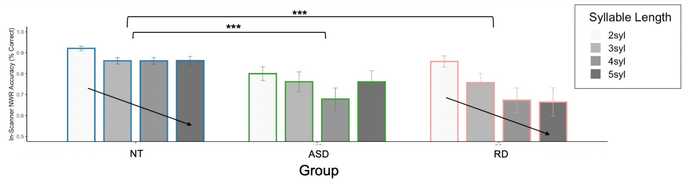

Figure 3. In-scanner performance on nonword repetition task. Mean accuracy of nonword repetition within each condition for the NT, ASD, and RD groups. A downward slanted arrow represents a significant effect of syllable length. *** $p < 0.001$.

The autism group had reduced activation to increasing syllable length in the supplementary motor area.

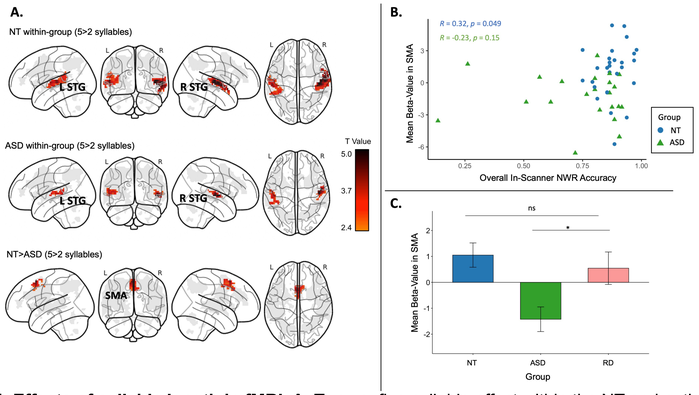

Figure 4. Effects of syllable length in fMRI. A. Two vs. five-syllable effect within the NT and autism groups and the difference between the two groups (cluster-forming nonparametric $p < 0.01$, cluster-level FWE-corrected $p < 0.05$). **B.** Activation at SMA was positively correlated with in-scanner nonword repetition performance in the NT group, but not the ASD group. **C.** The RD group did not vary from the NT group in SMA activation magnitude but was significantly higher than the ASD group.* $p < 0.05$.

The autism group had lower decoding accuracy (5 vs. 2 syllables) in the speech production network.

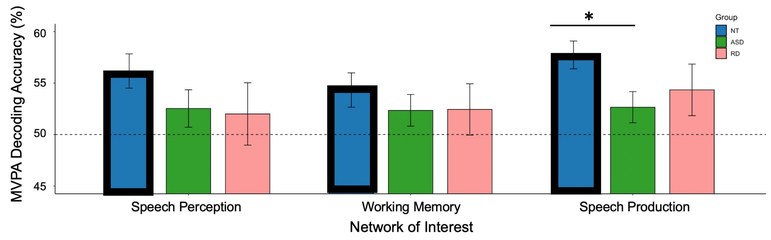

Figure 5. MVPA decoding accuracy for two-syllable vs. five-syllable nonword repetition trials. Above-chance decoding accuracy, corrected for multiple comparisons, is indicated by thick borders. * pairwise group differences $p < 0.05$.

Discussion

Results add to a growing literature showing broad **motor system differences in ASD**, including motor differences related to speech and language.

Data emphasize the interaction between **atypical motor system and language functions** in autistic children by demonstrating that the motor system is **disengaged** during a phonological working memory task.

Speech-production network and SMA-related differences were **not observed** in a group of **non-autistic children** with a **reading disability,** and **held in autistic children regardless of concurrent language skills.**

Brain-based alterations in **motor planning** that underlie nonword repetition may **uniquely** contribute to **phonological working memory difficulty** in autism.

Speech production is an important part of phonological working memory that has been **largely neglected** in previous phonological working memory research.

Limitations: Sample size, adult-derived NOIs, age range

Future Directions

How do motor functions in the verbal/nonverbal domains predict language learning outcomes in autistic children?

How do motor functions relate to language learning in other communication disorders with concomitant motor and working memory difficulties?

References

Scan QR code for complete reference list:

Contact: Amanda_Obrien@g.harvard.edu

This work was funded by National Institutes of Health Grant No. R01DC011339; AMO was funded by NIH Training Grant: 5T32DC000038-29.