Executive Function and Second Language Phonological Processing

Brandin Munson, Pilar Archila-Suerte, & Arturo Hernandez
University of Houston

Introduction

- A major hurdle in acquiring the phonology of two languages is the differentiation of two different sets of language phonemes.
- The importance of speech sound learning has been demonstrated in monolingual infants, who show advanced language abilities at 24 months and at 30 months when they neurally entrench to native sounds early in the first year of life (Kuhl et al., 2005).
- Recent studies have shown activation differences between bilinguals and monolinguals in areas associated with executive function when listening to second language syllables (Archila-Suerte, Zevin & Hernandez, 2015; Archila-Suerte, Zevin, Ramos & Hernandez, 2013).

Main Aim:

- Test the possibility that unbalanced bilinguals utilize brain areas associated with executive function differently from balanced bilinguals during a phonemic differentiation task.

Methods

Participants:

- 29 Spanish-English bilingual children (16 girls), average AOA = 4 years (SD=0.32). Age Range 6-10 years old.

Balanced Bilinguals:

- N = 16. Those who had less than 8 points of discrepancy in proficiency between languages, according to the Woodcock.

Unbalanced Bilinguals:

- N = 13. Those who had 10-29 points of discrepancy in proficiency between languages. Significantly more proficient in Spanish than in English ($t(12)=4.3$, $p<0.001$).

Measures:

- **Woodcock-Munoz Language Proficiency Battery-Revised (Woodcock & Muñoz-Sandoval, 1995).** Oral and receptive abilities in English and Spanish assessed using the tests of picture vocabulary and listening comprehension.
- **Language History Questionnaire.** AoA, percent of time each language is used, related information (e.g., travel outside the U.S. and SES).

Stimuli:

- English vowels /æ/, /ɒ/, /ʌ/ presented in the context of the syllables 'saf,' 'sof,' and 'suf.' These were each paired with one another (e.g., saf-saf, saf-sof, sof-suf) during presentation within the MRI scanner.

Task & Procedure:

- While watching a muted video clip of Planet Earth, syllable pairs played during a silent period via the MRI headphones. Children passively listened to the stimuli during scanning.

MRI:

- 3 Tesla Magnetom Trio (Siemens) at the Human Neuroimaging Lab of the Baylor College of Medicine in Houston, Texas.
- Regions of Interest (ROI's): 1) bilateral inferior frontal gyrus, 2) bilateral middle frontal gyrus, 3) bilateral supplementary motor area, 4) bilateral anterior cingulate cortex, 5) bilateral superior temporal gyrus, and 6) middle temporal gyrus.

Results

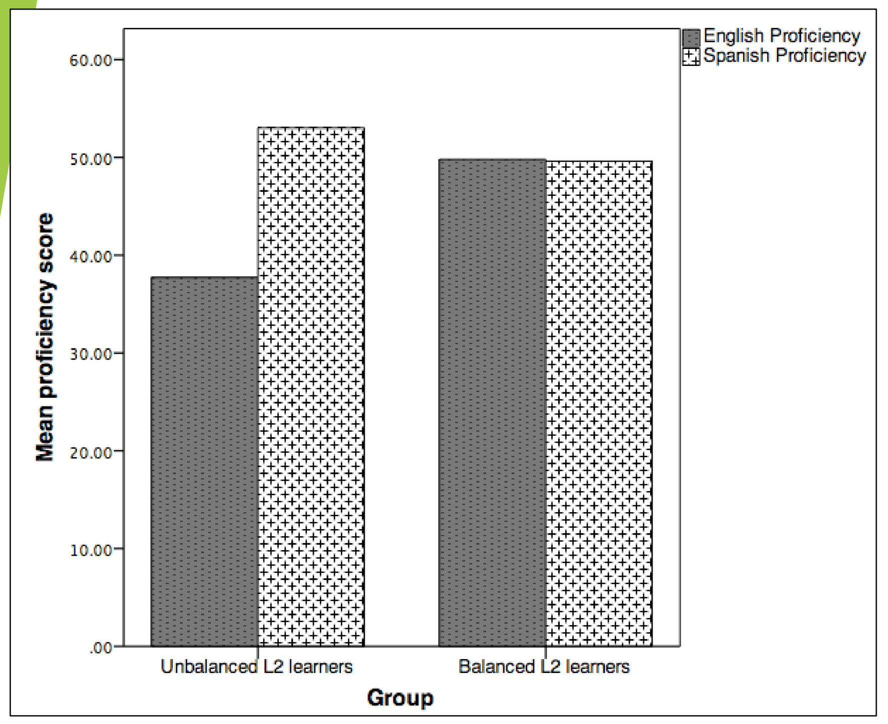

Figure 1
Mean proficiencies by group.
Unbalanced t(12) = 4.3, p < .0001

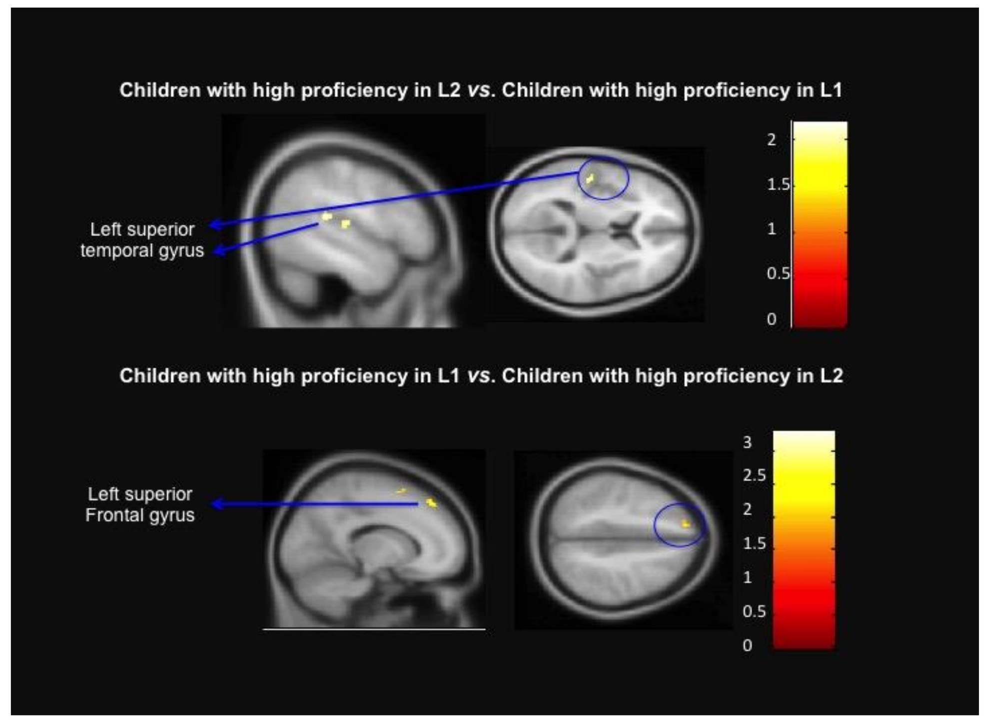

Figure 2
Top: *High Bilingual L2 Prof. – High L1 Prof.*
Bottom: *High L1 Prof. – High L2 Prof.*

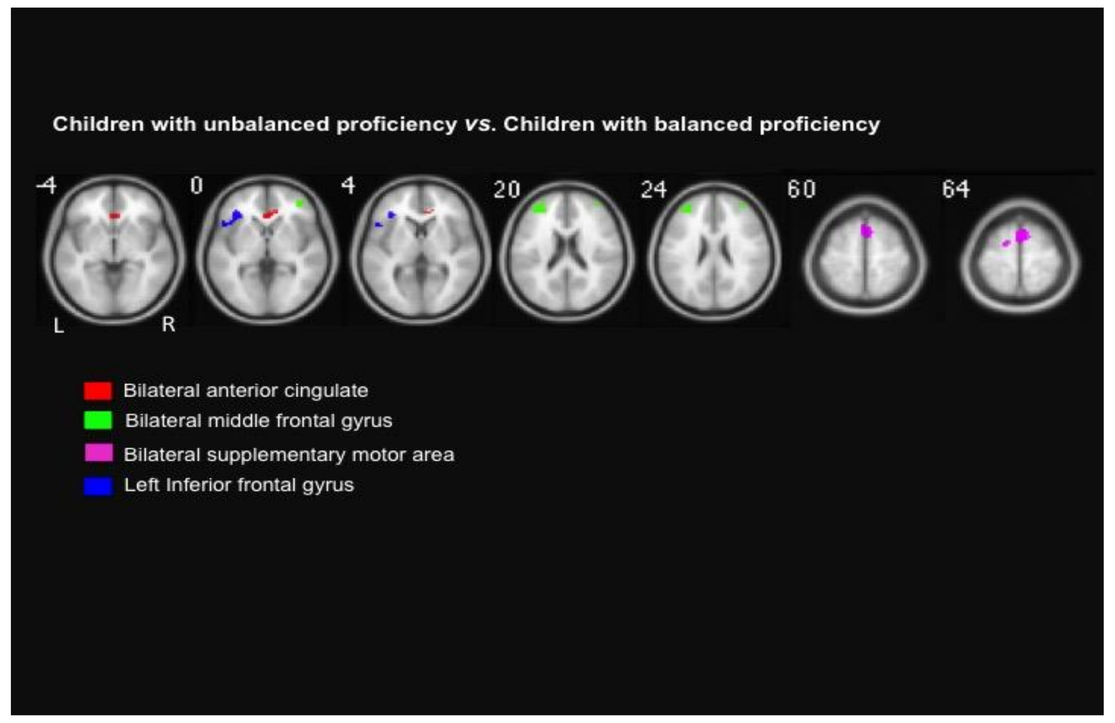

Figure 3
Unbalanced – Balanced ROI Activity

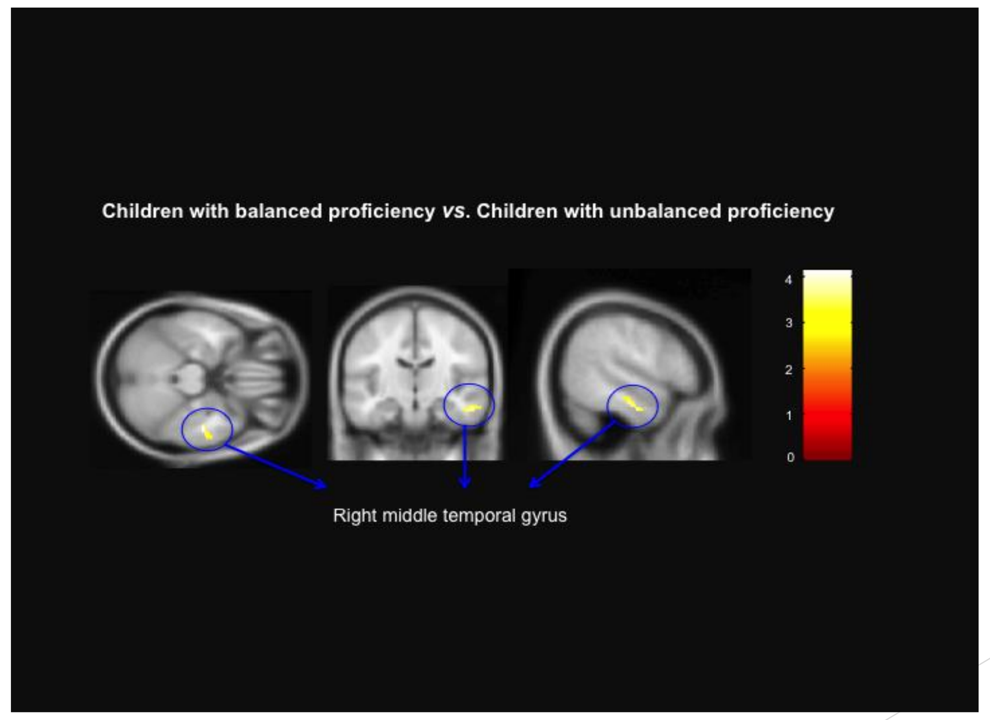

Figure 4
Balanced – Unbalanced ROI Activity

Conclusion

- During a phonemic differentiation task, different regions activated for bilinguals more proficient in L1 (left SFG) vs. bilinguals more proficient in L2 (left STG).
- Balanced bilinguals recruit only the right temporal gyrus relative to unbalanced bilinguals.
- Unbalanced bilinguals bilaterally recruit areas associated with executive function, suggesting greater reliance upon cognitive control processes to aid L2 speech perception.

Children with unbalanced proficiency vs. Children with balanced proficiency

	Cluster magnitude	Peak T	MNI coordinate	Peak threshold p-value
Left inferior frontal gyrus				
	202	2.69	-48 16 -2	0.05
Left middle frontal gyrus				
	209	2.44	-34 48 20	0.05
Right middle frontal gyrus				
	28	2.31	36 52 24	0.05
	32	1.98	40 48 0	
Left anterior cingulate cortex				
	21	2.77	0 28 -2	0.05
Right anterior cingulate cortex				
	77	3	4 30 -2	0.05
Left supplementary motor area				
	124	3.22	0 12 64	0.05
	30	2.49	-16 2 64	
Right supplementary motor area				
	135	3.05	2 10 64	0.05
Children with higher proficiency in L2 > Children with higher proficiency in L1				
Left superior temporal gyrus				
	60	2.19	-48 -34 16	0.05
	22	2.07	-50 -20 12	
Children with higher proficiency in L1 > Children with higher proficiency in L2				
Left superior frontal gyrus				
	48	3.34	-16 8 64	0.05
	45	2.56	-14 38 50	

Children with balanced proficiency vs. Children with unbalanced proficiency

	Cluster magnitude	Peak T	MNI coordinate	Peak threshold p-value
Right middle temporal gyrus				
	183	3.74	56 -8 -26	0.05

Archila-Suerte, P., Zevin, J., & Hernandez, A. E. (2015). The effect of age of acquisition, socioeducational status, and proficiency on the neural processing of second language speech sounds. *Brain Lang, 141*, 35-49.
Archila-Suerte, P., Zevin, J., Ramos, A., & Hernandez, A. (2013). The Neural Basis of Non-Native Speech Perception in Bilingual Children. *NeuroImage, 67*, 51-63.
Kuhl, P., Conboy, B., Padden, D., Nelson, T., & Pruitt, J. (2005). Early speech perception and later language development: Implications for the "Critical Period". *Language Learning and Development, 1*(3), 237-264.