Developmental differences in neural oscillations supporting online sentence processing

Julie M. Schneider[1], Alyson D. Abel[2], Anna E. Middleton[1], Diane Ogiela[3] & Mandy J. Maguire[1]

University of Texas at Dallas[1], San Diego State University[2], Idaho State University[3]

PURPOSE

The current study uses both **ERP** (e.g., P600, N400) and **time frequency** (e.g., theta, beta) analyses to investigate developmental differences in the underlying neural processes engaged during a grammaticality judgment task to better understand the development of auditory language processing.

BACKGROUND

- Real-time language comprehension is a complex task that requires rapid integration of semantic and syntactic information, which continues to develop through age 12 or later[1]
- Event Related Potential Research:
  - Children display a later, larger, widely distributed N400 (semantic processing)[2]
  - Children display a larger, later P600 (syntactic processing) [2]
- Time Frequency Analysis Research:
  - Increases in theta related to semantic integration in adults[3]
  - Decreases in beta related to syntactic unification[4]

METHODS

- **Participants.**

Right-handed, monolingual English speakers

  - 18 Adults: ages 18-31 years (9 males) *M* =24.41, *SD* = 4.37
  - 18 Children: ages 10-12 years (9 males) *M* =10.94, *SD* = 0.94

- **EEG Equipment.**

Neuroscan EEG System, 62 electrode cap

- **Methods.**

Performed 160 grammatical judgments; 80 correct & 80 incorrect. Only data from correct sentences were included in this analysis.

Each epoch began 500 msec prior to the onset of the verb and ended 1500 msec after verb onset.

- **Example Stimuli.**

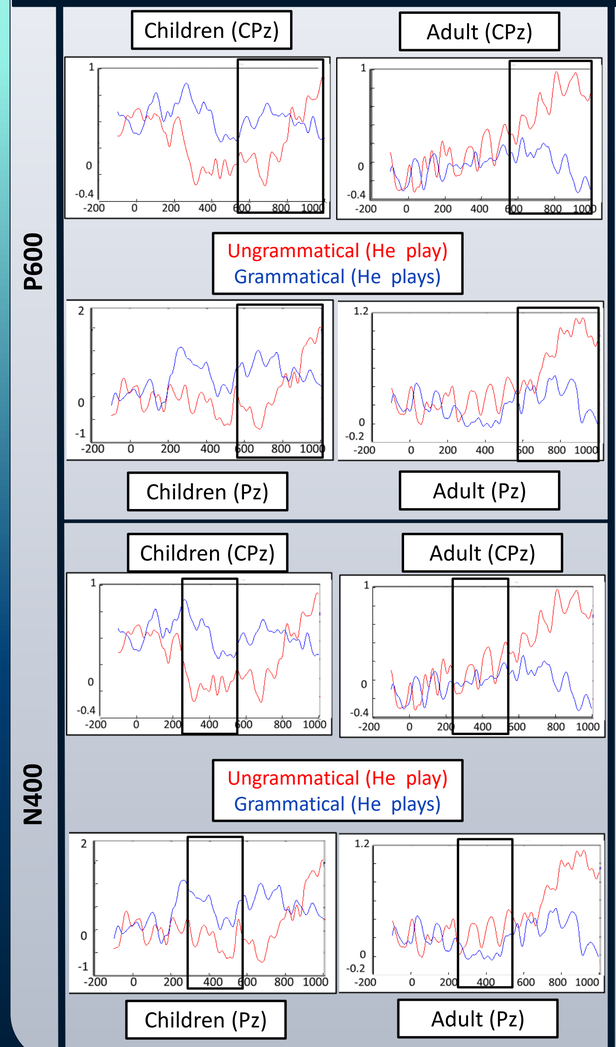
Grammatical	**After school she goes/they go to the park.**
Ungrammatical	**After school she go/they goes to the park.**

BEHAVIORAL RESULTS

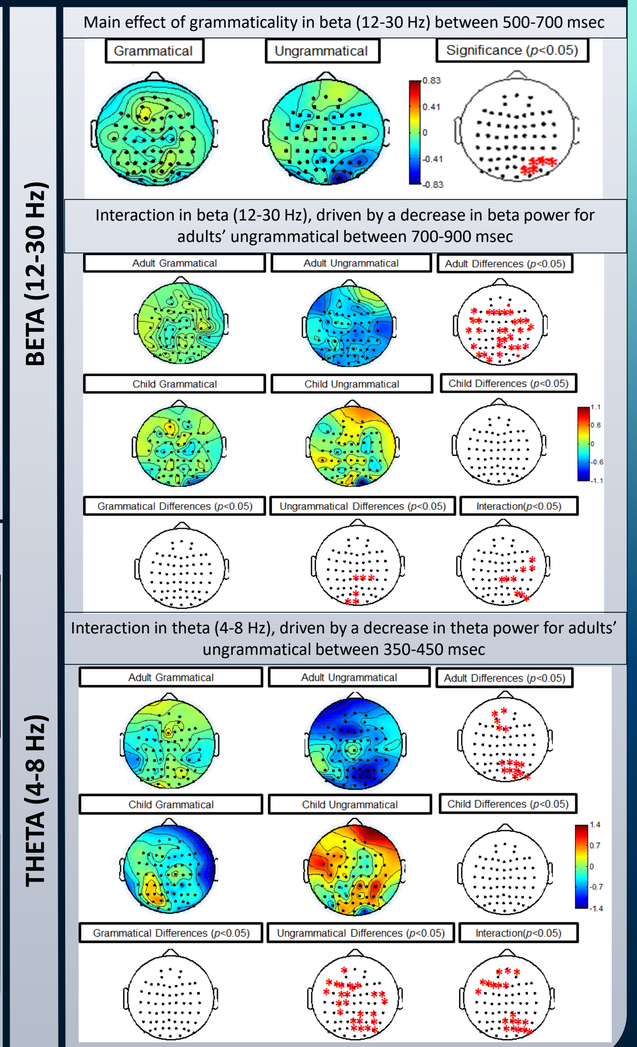
CHILDREN	ADULTS
Misidentified 17.17%	**Misidentified 6.13%**

$F(1,35)= 12.06$, $p<0.001$

ERP RESULTS



TIME FREQUENCY RESULTS



TIME FREQUENCY ANALYSIS

- Event-related spectral perturbations (ERSP) were calculated by Fourier transforming, magnitude squaring, and suitably normalizing each window using the EEGlab Toolbox in Matlab.
- Data were averaged across trials and subjects, and computed using the log power values minus the baseline[5]
- Within EEGLAB, an interactive Matlab toolbox, random permutation statistical analysis of the EEG data were performed. Only statistically significant clusters of 3 or more adjacent electrodes were included.

CONCLUSIONS

Few developmental differences existed during grammatical processing; however, many differences existed during processing of a syntactic error.

P600 & Beta

- Children displayed a P600 that was later, and smaller than that of adults
- Adults demonstrated a significant decrease in beta power that was absent in children

N400 & Theta

- Children displayed a significant N400
- Adults demonstrated a significant decrease in theta power that was absent in children

These findings suggest children exhibited neural markers more commonly associated with semantic processing; similar to research by Hahne, Eckstein & Friederici (2004) which found a sustained negativity and lack of P600 in response to errors in children less than 13 years of age.

DISCUSSION

This study supports previous claims that the neural underpinnings of syntactic processing continue developing in adolescence, and adds to them by identifying the role of theta and beta in supporting that development

REFERENCES

1 Atchley, R. A., Rice, M. L., Betz, S. K., Kwasney, K. M., Sereno, J. A., & Jongman, A. (2006). A comparison of semantic and syntactic event related potentials generated by children and adults. Brain and Language, 99, 236-246.

2 Hahne, A., Eckstein, K., & Friederici, A. D. (2004). Brain signatures of syntactic and semantic processes during Children's language development. *Journal of Cognitive Neuroscience*, *16*(7), 1302-1318.

3 Hald, L. A., Bastiaansen, M. C. M., & Hagoort, P. (2006). EEG theta and gamma responses to semantic violations in online sentence processing. *Brain and Language*, *96*(1), 90-105. doi:10.1016/j.bandl.2005.06.007.

4 Bastiaansen, M. C. M., Magyari, L., & Hagoort, P. (2010). Syntactic unification operations are reflected in oscillatory dynamics during on-line sentence comprehension. *Journal of Cognitive Neuroscience*, 22, 1333-1347. doi:10.1162/jocn.2009.21283.

5 Delorme, A. & Makeig, S. (2004) EEGLAB: an open toolbox for analysis of single-trial EEG dyanmics including independent component analysis. *Journal of Neuroscience Methods*, 134, 9-21.

6 Maris, E., & Oostenveld (2007). Nonparametric statistical testing of EEG- and MEG- data. *Journal of Neuroscience Methods*, *164*, 177-190.