Developmental differences in neural oscillations supporting the identification of novel word meaning from context

Jacob Momsen[1,2] Julie M. Schneider[3,4], Alyson D. Abel[1]

[1]San Diego State University
[2]University of California, San Diego
[3]Louisiana State University
[4]The University of Delaware

Background

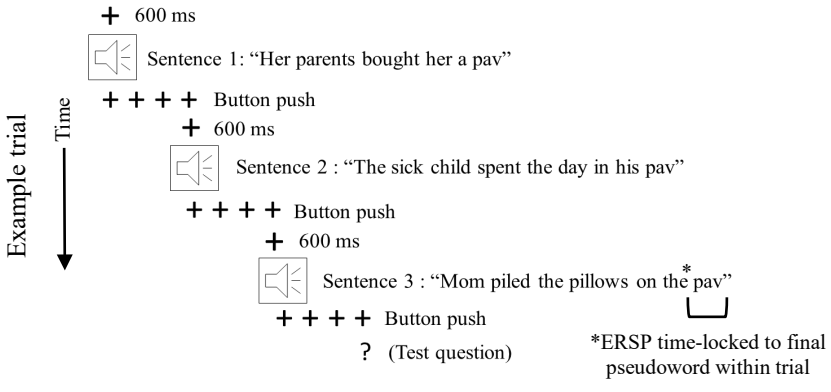
As older children and adolescents continue to develop their language abilities, learning words implicitly from their context is a primary means of vocabulary growth. The current study investigated the neural correlates that underlie how school-aged children and adolescents identify the meaning of novel words embedded within sentence contexts. In particular, we test how differences in the brain response to novel words in context differ as a function of offline language aptitude while controlling for age.

Methods

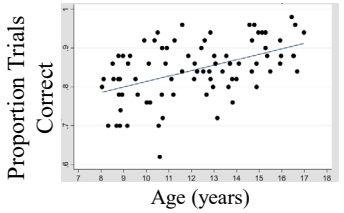
Children between the age of 8 and 16 (n=82; 45 females; mean age = 12 yrs. 2 mos.) completed a meaning-identification task requiring participants to generate plausible word meanings for unfamiliar words embedded across a series of spoken sentence contexts while EEG was recorded from 62 scalp locations.

Children listened to 50 trials—each containing three semantically related sentences and all ending in the same pseudoword . At the end of a trial, children attempted to verbally provide the real sentence-final word that the pseudoword was replacing, which required them to estimate a word meaning using information from the relevant sentence contexts.

We used a linear mixed-effects analysis to examine trial-by-trial relationships between the time-frequency dynamics[1] of the EEG signal related to pseudoword processing and successful performance on the meaning-identification task.
Task performance (correct or incorrect meaning identification), as well as age and language ability, as measured using the Core Language Score subtests of the CELF-5[2] , were modeled as predictors of the ERSP response to pseudowords.



Word Identification Performance

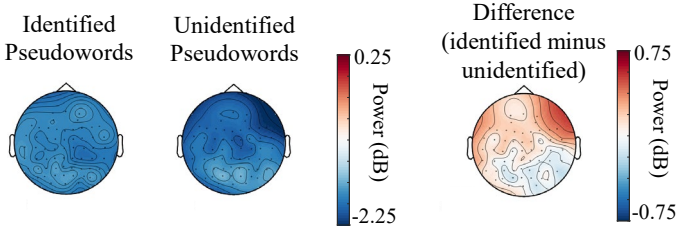


Mean performance accuracy across all children was relatively high (Mean = 84.5%; σ = 7.5%; Range: 62-98%). A simple linear regression predicting performance accuracy revealed a relationship between both age and language scores with overall accuracy on the word learning task (R^2 = 0.28; $p < 0.001$). Age exhibited a stronger relationship with task performance (β = 3.6%; s.e. = 0.72%; $p < 0.001$)

Task-relevant ERSP activity

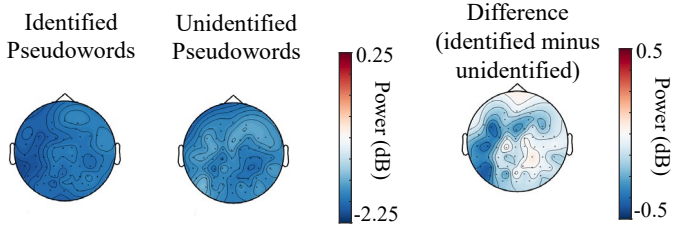
Beta Band

Pseudowords processed in trials where meaning was subsequently identified were associated with less beta band suppression, especially over frontal channels (Main effect Accuracy: β= 0.13; SE = 0.06; P < 0.025).



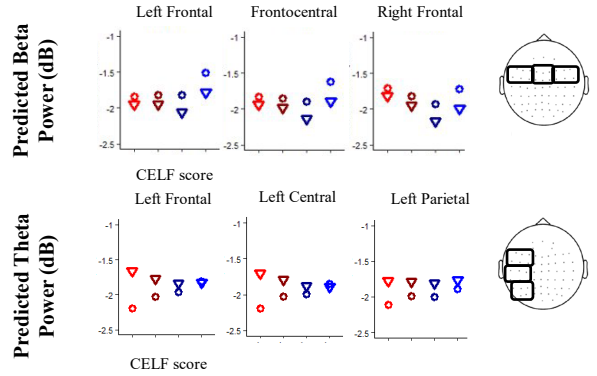
Theta Band

Successful task performance was also related to power modulation in the theta frequency range over the left hemisphere (Accuracy x Hemisphere: β= -0.15; SE = 0.05; P < 0.01).
More positive theta values in response to pseudowords was associated with trials where meaning was not successfully identified.



Unique influence of language skills on ERSP signature supporting meaning identification

Predicted model fits for the interactions between language ability and accuracy on the meaning identification task



Interaction with CELF scores revealed that children with superior language skills showed greater task-related changes in **beta band** (Accuracy x CELF: β= 0.05; SE = 0.02; P < 0.01).

Differences due to word identification performance in **theta band** activity was negatively associated with language abilities (Accuracy x CELF:β= 0.19; SE = 0.06; P < 0.01).

Incorrect trials
Correctly identified pseudowords

CELF scores < -1 SD
-1 SD < CELF scores < 0 SD
0 SD < CELF scores < 1 SD
CELF scores > 1 SD

Conclusions

Greater language abilities were associated with larger task-relevant changes in beta band activity. Alternatively, language skills were negatively associated with performance-relevant changes in oscillatory activity in theta band range. These effects reflect the how the neural implementation of meaning mapping from context—an important skill for word learning—is uniquely influenced by the maturity of language abilities irrespective of age.

In the context of language comprehension, beta band dynamics have been associated with the state of top-down predictive coding mechanisms sensitive to certain probabilistic features of discourse such as word surprisal[3,4] . Theta band activity may alternatively reflect conflict monitoring or controlled memory retrieval for unexpected lexical representations[5] . As such, the current data may suggest that precocious aptitude for language specifically supports a shift in the predominance or efficacy of online, expectation-based processing mechanisms for generating novel word meaning from context.

References

1) Schneider, J. M., Abel, A. D., Ogiela, D. A., Middleton, A. E., & Maguire, M. J. (2016). Developmental differences in beta and theta power during sentence processing. Developmental Cognitive Neuroscience, 19, 19-30.
2) Wiig, E. H., Semel, E., & Secord, W. A. (2013). Clinical Evaluation of Language Fundamentals–Fifth Edition (CELF-5)
3)Lewis, A. G., & Bastiaansen, M. (2015). A predictive coding framework for rapid neural dynamics during sentence-level language comprehension. Cortex, 68, 155-168
4)Armeni, K., Willems, R. M., Van den Bosch, A., & Schoffelen, J. M. (2019). Frequency-specific brain dynamics related to prediction during language comprehension. NeuroImage, 198, 283-295
5)Rommers, J., Dickson, D. S., Norton, J. J., Wlotko, E. W., & Federmeier, K. D. (2017). Alpha and theta band dynamics related to sentential constraint and word expectancy. Language, Cognition and Neuroscience, 32(5), 576-589.