

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



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 dynamics¹ 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-5², were modeled as predictors of the ERSP response to pseudowords.

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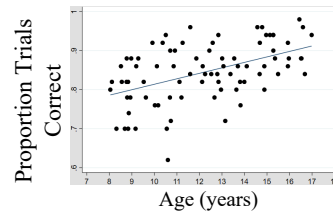
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Word Identification Performance



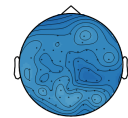
Mean performance accuracy across all children was relatively high (Mean = 84.5%; $\sigma = 7.5\%$; Range: 62-98%). A simple linear regression predicting performance accuracy revealed a relationship between both age and language scores with overall accuracy on the word learning task ($R^2 = 0.28$; $p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

Task-relevant ERSP activity

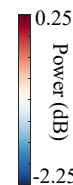
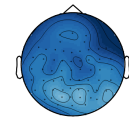
Beta Band

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

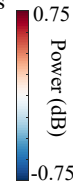
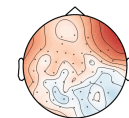
Identified Pseudowords



Unidentified Pseudowords



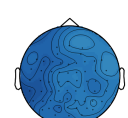
Difference (identified minus unidentified)



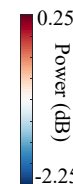
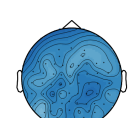
Theta Band

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

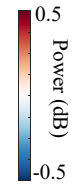
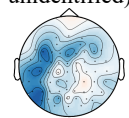
Identified Pseudowords



Unidentified Pseudowords

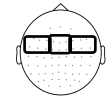
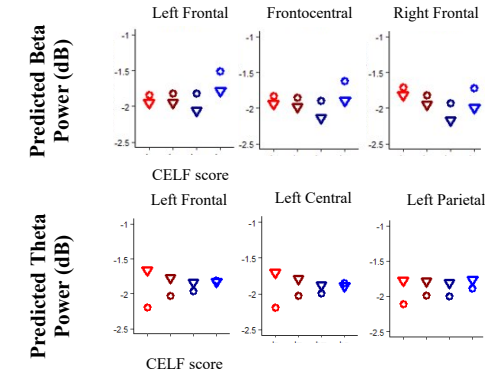


Difference (identified minus unidentified)



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: $\beta = 0.05$; 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: $\beta = 0.19$; SE = 0.06; $P < 0.01$).

CELF scores < -1 SD
-1 SD < CELF scores < 0 SD
0 SD < CELF scores < 1 SD
CELF scores > 1 SD
Incorrect trials
Correctly identified pseudowords

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 representations⁵. 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

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+ 600 ms
Sentence 1: "Her parents bought her a pav"

+ + + + Button push
+ 600 ms

Sentence 2: "The sick child spent the day in his pav"

+ + + + Button push
+ 600 ms

Sentence 3: "Mom piled the pillows on the pav"

+ + + + Button push
? (Test question)

*ERSP time-locked to final pseudoword within trial

Example trial

Time