Developmental differences in the neural mechanisms supporting natural sentence comprehension

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Purpose

Aim to clarify when complex language processes become mature in the brain, and to what extent the neural indices supporting early language comprehension become adult-like.

Background

- Natural speech comprehension occurs with relative ease and develops early in life.
- However, adult mastery of both semantic and syntactic processing continues to develop until 18 years or older[1-2]
- To date, most research has focused on written contexts and semantic and syntactic errors that are rarely, if ever, encountered in English [3-5]
- Only a handful of research studies have investigated the neural processes engaged during natural language comprehension in typically developing, school-aged and adolescent children[6-8]
- The goal of the current study is to characterize the neural correlates underlying the time-course of semantic and syntactic processing during real-time language comprehension in school-age and adolescent children (8-9, 12-13 years) using electroencephalography (EEG).

Methods

Participants.
Right-handed, monolingual English speakers
Children: *N* = 30, age range = 8-9 years
(Mage=9.1, SDage=.60, 18 males)
Adolescents: *N* = 31, age range = 12-13 years
(Mage=12.8, SDage=.58, 18 males)
Adults: *N* = 37, age range 18-31 years
(Mage=22.2, SDage=3.9, 10 males)

EEG Equipment.
•Neuroscan EEG System, 62 electrode cap

Methods.
•Performed grammaticality judgments for 160 sentences:
•80 semantic task & 80 syntactic task (30 sentences containing error within each condition).
•**Correct:** grammatically and semantically correct
•**Semantic Error:** unsuitable pairing of actions with agents
•**Syntactic Error:** intrusion/omission of a present participle (-ing) form of the verb

•The current study was designed to ensure that the correct agent-action pairing, semantic mismatch and grammatical error occurred on the same word within each sentence.

Stimuli & Analysis

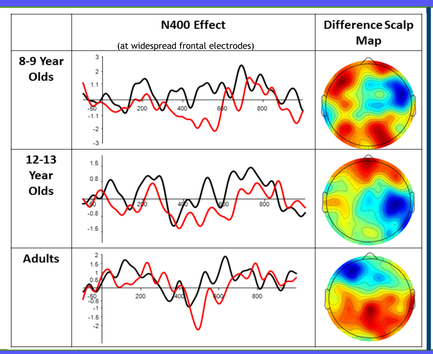
Sentence Type	Example stimuli involving an intrusion error.
Correct	Outside in the garden, the *hose* can *spray* water on the flowers.
Semantic Error	Outside in the garden, the *hose* can *bake* water on the flowers.
Syntactic Error	Outside in the garden, the *hose* can *spraying* water on the flowers.

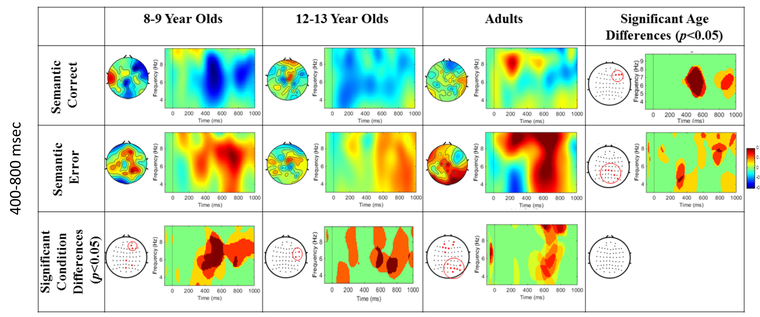
Analysis.
- EEG data was epoched from 500 msec before to 1500 msec after the target verb onset.
- Only trials in which participants responded to correctly were included in the analysis.

ERPs.
- The mean amplitude of the pre-stimulus interval (-100 to 0 msec) was subtracted from each time point in the post-stimulus interval.
- Single trials were averaged together to obtain a stable waveform ERP for each condition

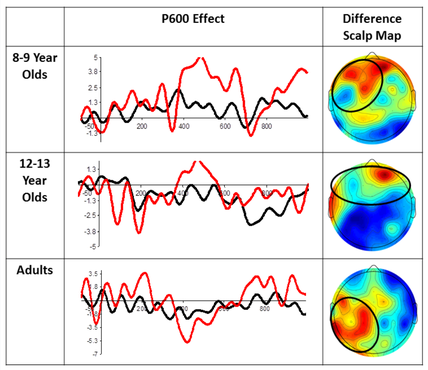
Time-Frequency.
- The mean ERSP was computed for all data channels (3-30 Hz) and a morlet wavelet was applied to each epoch.
- The mean baseline power at each electrode and frequency was subtracted.
- Statistical significance was determined using a monte-carlo permutation analysis [9]

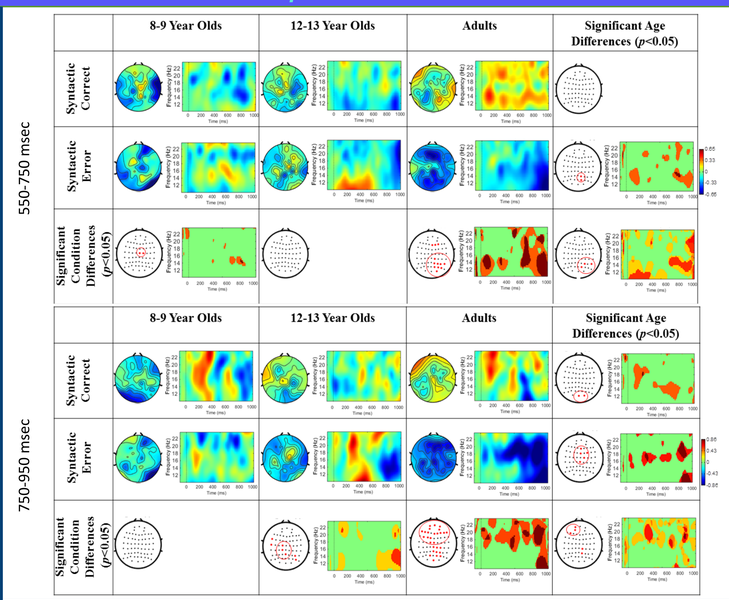
Semantic Task: N400/Theta





Syntactic Task: P600/Beta





Conclusions

Semantic Development:
- There were no developmental differences in the N400
- Increases in theta, related to semantic processing, were greater for 8-9 year olds than 12-13 year olds and adults.

Main Point: N400 may be too gross a measure to identify more subtle aspects of semantic development that are ongoing in early school-aged children

Syntactic Development
- Syntactic errors resulted in a larger P600 and greater beta decrease than correct sentences
- The location of the P600 and the amplitude of beta decreases differed as a function of age

Main Point: Specialization of syntactic skills is ongoing through adolescence and children may recruit an alternative neural process to identify a syntactic error, which beta is not sensitive to.

Take Home Message

Our findings suggest the neural substrates underlying semantic processing reach adult-like levels at a younger age.

However, syntactic skills develop over a protracted time course and may require recruitment of additional neural mechanisms to support comprehension of natural language.

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