Reading, The Brain, and Reading the Brain:
does working memory affect mean N400 amplitude in children and adults?

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Abstract

The connection between working memory (WM), development, and N400 amplitude was explored using a Daneman and Carpenter (1980) complex-span task and a Kutas and Hillyard (1980) semantic priming task. The priming task used three types of sentence endings: congruous, moderately incongruous, and strongly incongruous. Children age 8-12 and adults age 18-24 completed both tasks. It was hypothesized that there would be a correlation between N400 amplitude and working memory scores in both ages. It was also hypothesized that strongly incongruous sentences would have larger N400's than moderate in both children and adults. The results show a moderate correlation between WM capacity and N400 amplitude in adults, but not in children. Additionally, adults' N400's in the strongly incongruous condition were significantly stronger than the moderately incongruous; this was not shown in children.

Background

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It has been found that executive function, working memory, and reading comprehension are factors in N400 amplitude (Gunter et al, 1995, 2003; Rößner et al, 1999; Salisbury, 2004; Kumar and Debruile, 2004). Additionally, there are developmental differences in N400 and P600 amplitudes (Holcomb, Coffey, Nicol, 1992). However, the relation between these abilities has not been explored.

Previous research suggests

•Complex Reading Span of WM (Daneman and Carpenter, 1980) has been correlated to reading comprehension across development (Siegel, 1994)
•Reading comprehension has been correlated to the N400 (Gunter et al 2003, 2005; Salisbury, 2004)
•Children elicit larger N400's than adults for physiological reasons (Holcomb et al, 1992; DeBoer, 2005)

However, no published studies have explored the role of working memory in language processing using a semantic priming task (Kutas and Hillyard, 1980). The purpose of the current research is to explore the role of WM in N400 amplitude in both adults and children

Methods
Participants

Total: 21 children (8 boys, 13 girls) and 28 adults (8 men, 19 women, 1 genderqueer/other). Children were aged 8-12 (m=10.0, SD=1.0 years), adults were 18-22 (M=20.6, SD=1.3years)

ERP sample: A total of 31 subjects (n=21) were included (15 children, 16 adults). Six adults were not included due to programming errors, additional subjects were excluded based on alpha intrusion, noise level, and accepted number of trials after blink rejections. All participant were seated in a comfortable chair in a darkened, quiet room.

Electrophysiological Recordings

•32-channel tin Electro-cap (Electro-Cap International) based on the standard international 10-20 system.
•Mastoid referenced; impedances were below 5k ohms for all subjects.
•Data was recorded using a Synamps Amplifier with Scan 4.2 (2001) software and was digitized at the rate of 250 Hz using a bandpass filter of .1 to 100 Hz.
•Vertical and horizontal electro-oculograms (EOGs) were recorded to eliminate blinks and eye movement.
ERP Data Analysis
•A window 275 to 475ms post-final-word was chosen to examine the N400.
•ERP's were filtered from .1 to 30Hz, baseline corrected, and artifact rejected -50/+50 for eyeblinks.

Methods (cont.)

Working Memory Span

•Self-paced reading span task based on Daneman and Carpenter (1980) using index cards. Participants were presented sets of sentences (2 to 6 sentences each).
•A Blank card at the end of a set was the cue to recall the last words of all the sentences presented.
•Three blocks with a set of 2 to 6 sentences, 60 sentences per block were presented.[1] Partial-credit score (Conway et al., 2005) was used; order was not counted.

> **Sample 3-Sentence Set:**
> *Yesterday, Mary got to ride a camel at the zoo.*
> *The fan circulated the air through the damp apartment.*
> *The alligator attacked several people in a Florida swamp.*
>
> Recall: zoo, apartment, swamp

Forced-Choice Semantic Priming Task:

EEG activity was recorded while sentences were presented one word at a time using eprime. 104 Sentences were used in total, 35 congruous, moderately incongruous, and strongly incongruous.[2] The prompt "Did that sentence make sense" occurred 1s after the last word, and served as a cue to respond and a blink-break.

> **Sample Sentences:**
> Congruous: *We put syrup on the pancakes.*
> Moderately Incongruous: *The parking lot was filled with lobsters.*
> Strongly Incongruous: *They raised pigs on the family lemon.*

[1]Sentences were generated based on children's books, magazines, and previously used semantic priming/WM stimuli. They were double-checked for reading-level appropriateness by a 5th grade teacher.
[2]57 anonymous undergraduate rates confirmed the sentence congruity by ranking them on a scale of 1-5 (with 5 being the most congruous). There was an overall inter-rater reliability of 93 (Cronbach's Alpha). These were then ranked and divided into thirds: one-way ANOVA confirmed the three sentence types were significantly different in ranking. Anecdotally, several adult subjects stated that it seemed that 1/3 made sense, 1/3 didn't, and 1/3 could go either way. Both WM and the Semantic Priming sentences were 7-9 words long.
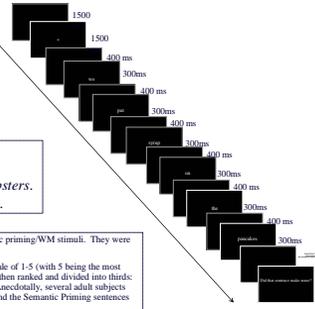
Results
Working Memory

Total Working Memory Scores

Adult score: Mean=49.7 (SD=12.0), range: 35 to 59.
Children: Mean=39.2 (SD=6.7), range of: 24 to 52.
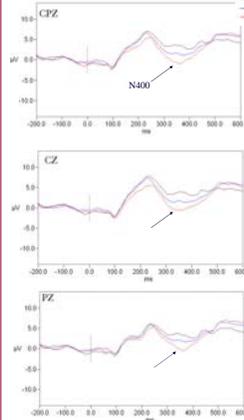Scores were significantly different between children and adults: (t(48)=-27.41, p<.001)

WM of ERP Participants

Adult Score: Mean=46.3 (SD=6.0), range of 35 to 55.
Children's Score:Mean= 40.8 (SD=7.3) range of 24 to 52.
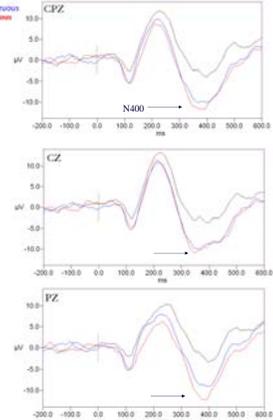Scores were significantly different between children and adults: (t(30)=33.59 p=.016).

Results (cont.)

Electrophysiological Data

Adult Data

Child Data

Correlation to Working Memory:

•Adults: Trend interaction (F(2, 14)=3.38, p=.063).

•Children: Not significant

•Median Split: Significant
(3(Sentence type)Xscore repeated measures ANCOVA: (F(4, 50)=3.93, p=.008).
  (5 adults were low span, 3 children were high span; 2 adults and 1 child scored the median).

Results of T-Tests:

Adults:
Congruous vs. Moderate: (t(16)=-3.77, p=.002)*.
Congruous vs. Strong: (t(16)=-5.23, p<.001)*
Strong vs. Moderate: (t(16)=-2.48, p=.025)*
Children:
Congruous vs. Moderate: (t(14)=2.76, p<.001)*
Congruous vs. Strong (t(14)=-2.73, p=.016)*
Moderate vs. Strong: (p=.8)

Discussion

☙ There was a main effect of sentence type for children and adults as expected, based on previous studies (e.g. Atchley et al, 2006).

☙ The trend interaction of WM and N400 amplitude in adults suggests a role of WM in the N400 processes in adults, but not in children.

☙ Adults' N400's varied as a function of congruity (strong>moderate>congruous), however, while children showed larger N400's to strongly and moderately incongruous sentences the N400 did not differ between strongly and moderately incongruous sentences.
•**This suggests that children have more difficulty releasing from the preceding context of an implausible sentence (e.g. Trueswell et al., 1999; Traxler, 2002).**
•**Additionally, increased efficiency in lexical and semantic processing can be seen through changes in the N400 across development.**

References
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