

Identifying Phonological Awareness Deficits with Event-Related Brain Potentials

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Introduction

Proficiency in phonological awareness skills is fundamental to reading success [1, 2].

A significant proportion of reading problems are attributed to deficits in phonological awareness [3].

Behavioral studies have shown that reading difficulties may be remediated through intensive phonological training [4].

Event-Related Brain Potentials (ERPs) provide an innovative tool to study neural changes associated with language processing.

Few ERP studies have used paradigms sensitive to the most complex phonological processing skills, namely phonemic awareness (e.g., phoneme segmentation, phoneme blending).

Objectives

In the current study, ERPs were measured as participants performed a phonemic awareness task requiring them to actively manipulate individual phonemes (Fig. 1).

The objective was to determine if the neural marker for phonological processing, the Phonological Mismatch Negativity - PMN [5], would differ in participants with and without deficits in phonological processing (Table 1).

Participants in the Phonological Impairment (PI) group were enrolled in Spell Read P.A.T., a comprehensive program focusing on improving reading skills by combining elements of phonological and phonetic skill development with language-based reading and writing instruction.

The long term goal of this research program is to measure ERPs prior to the initiation of Spell Read training, and at specified time points during training (20, 40 hours, etc.).

Hypothesis

It was hypothesized that the PMN would be reduced and/or delayed in the PI group prior to training, but that neural changes associated with phonological training would manifest in electrophysiological changes (i.e., increase in PMN amplitude, and decrease in onset latency) as training progresses.

Methods

Participants in the control group were dextral with a mean age of 23.6 yrs.

Participants in the Adult PI group are dextral with a mean age of 28.3 yrs.

Participants in the Child & Adolescent PI groups range in age from 7-18.

All members of the PI group are enrolled in Spell Read P.A.T.

Members of the PI group are tested prior to Spell Read training (ERP and neuropsychological), and again at specified time-points during training (20, 40, hrs, etc.).

Electrophysiological recordings

Fifteen channels - using Ag/AgCl electrodes referenced to linked ears

Bandpass = 0.01 Hz to 30 Hz, digitized to 0.1-20 Hz; sampled at 500 Hz (epoched -100 to 800 ms)

EKG artifacts \pm 75 mV between -100 ms and 800 ms

PMN scored as the most negative point in the 200 ms to 350 ms interval

P300 scored as the most positive point in the 250 - 600 ms interval

Neuropsychological assessment

Neuropsychological assessment was conducted using a battery of tests selected to evaluate language, with particular emphasis on phonological processing skills (Table 1).

Phoneme Awareness task

A modified phoneme deletion task was used to assess spoken word recognition, and phonemic awareness.

Instructions to delete a consonant from a target word were presented aurally (duration = ~ 3 sec), followed (1 sec) by a spoken word (duration = 750 ms to 1 sec).

Spoken words were either correct or incorrect (.25 probability).

Statistical analyses

A Repeated Measures ANOVA with conservative degrees of freedom (Greenhouse-Geisser) was used to analyze data, and Tukey's HSD was used for post-hoc tests if necessary ($P < .05$).

Figure 1: Schematic of Experimental paradigm.

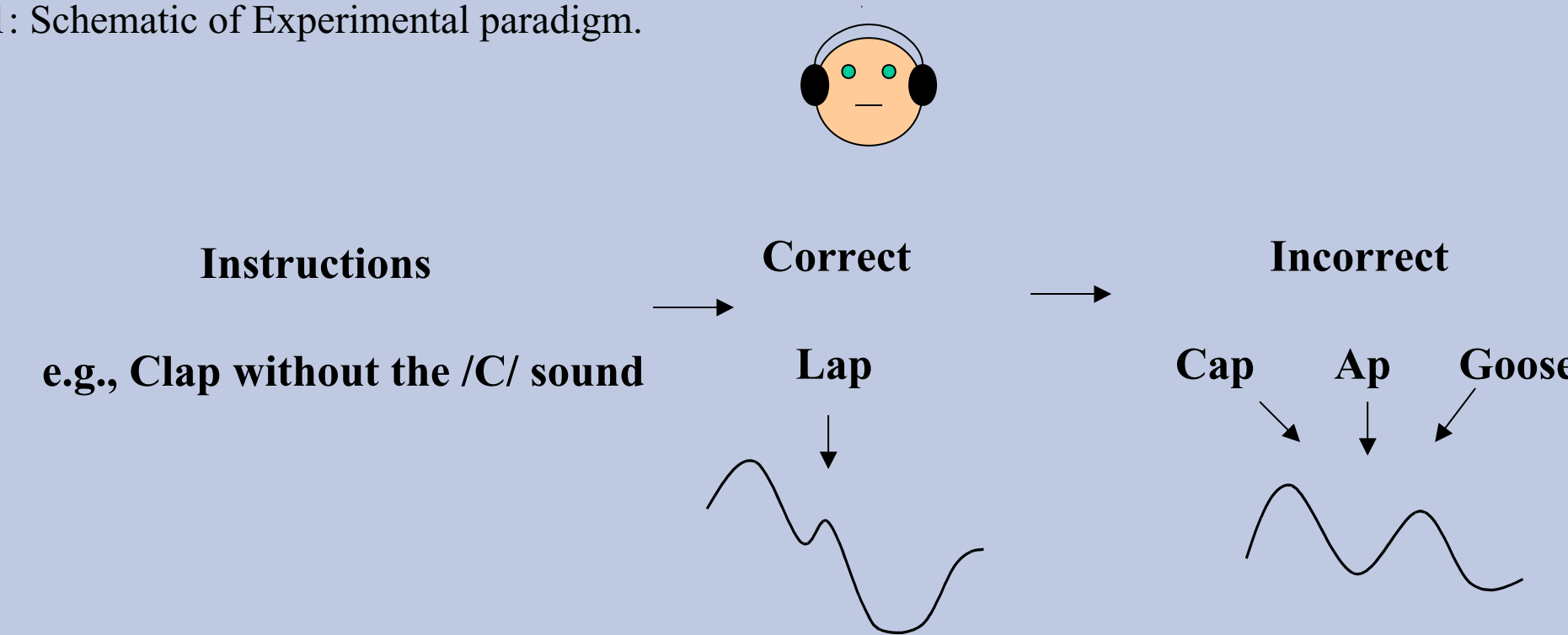


Figure 2: Grand Average ERPs of Control group participants (A) and those of an individual (B), recorded to Correct & Incorrect items following presentation of instructions to delete a consonant from a target word. The P300 (*) is largest in the Correct condition, while the PMN (↓) is largest in the Incorrect conditions: Wrong Consonant (WC) deleted, Consonant Cluster (CC) deleted & Irrelevant Word.

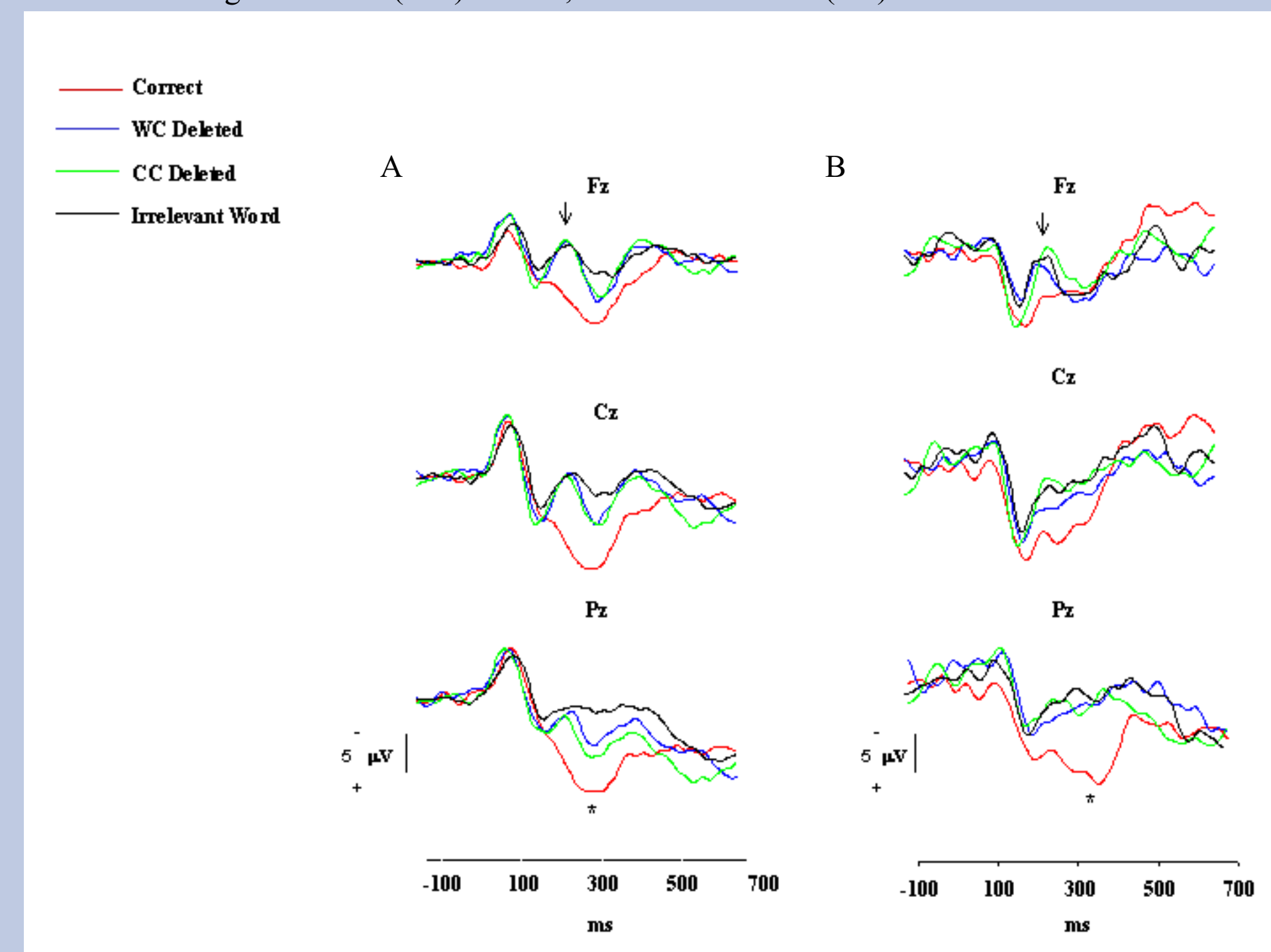


Table 1: Neuropsychological Assessment Profiles of the Control Group and the PI Group.

Control Group		PI Group		
Mean Age	23.6	28.3		
Mean Education	14.4	13.0		
Phonemes Deletion	95%			
Woodcock Mastery Reading Subtests				
Word Attack	16.9			
Word Identification	16.9			
Stage of Spell Read Training		Initial	20hrs	40hrs*
Phonological Processing				
1. Auditory				
a) Synthesis	65%	91%	100%	
b) Analysis	55%	89%	100%	
c) Listening	64%	90%	100%	
2. Auditory/Visual				
a) Single Phoneme Recognition				
Vowels	8.5/18	13/18	18/18	
Consonants	15.8/26	23/26	26/26	
b) Spelling - CVCs (pseudowords)	47%	87%	97%	
Woodcock Mastery Reading Subtests				
Word Attack	5.5	7.1	8.6	
Word Identification	8.4	9.1	9.2	

*Results shown based on completion of first half of program

Figure 3: Grand Average ERPs of Adult participants in the PI group and those of an individual recorded under the same experimental conditions as in Fig. 3. While a P300 (*) is elicited in the Correct condition, the PMN (↓) is not readily apparent in the waveforms.

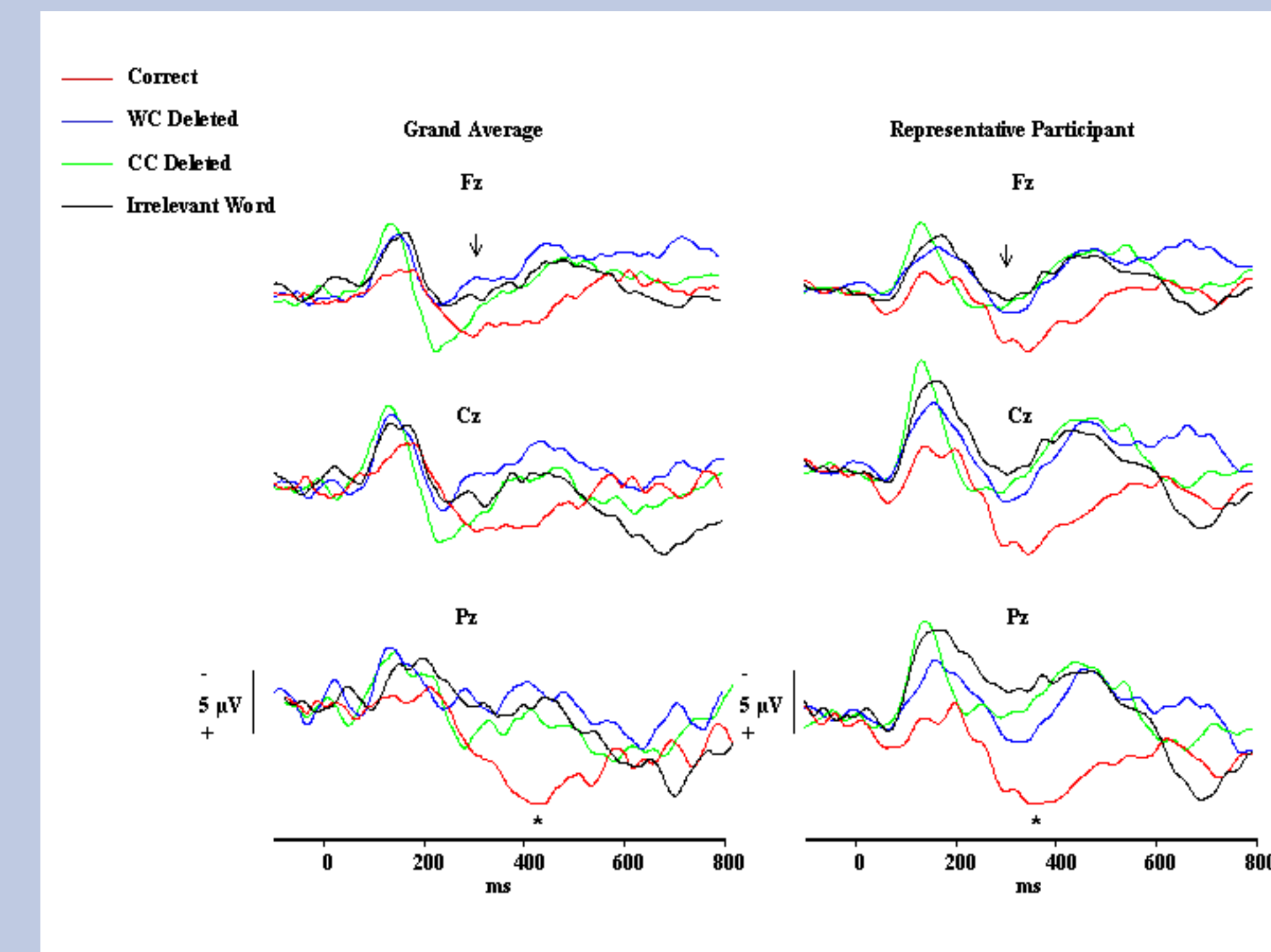
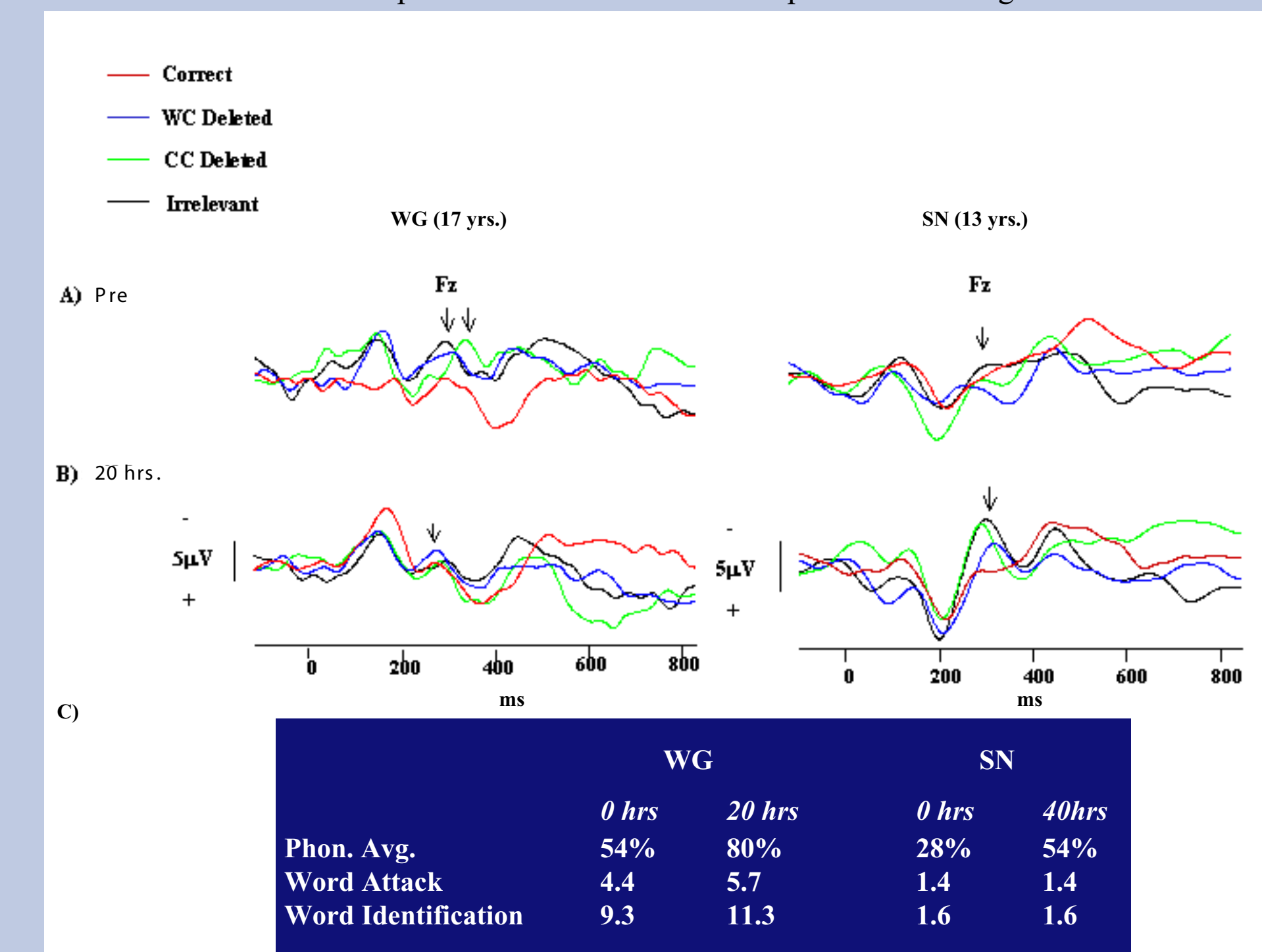


Figure 4: ERPs of 2 adolescent participants (WG & SN) enrolled in Spell Read, recorded prior (A) to and after 20 hours (B) of Spell Read training. WG: Prior to Spell Read training the PMN was delayed (i.e., 340 ms) when the consonant cluster (CC) was deleted. However, following 20 hours of Spell Read training, the onset of the PMN was the same for all conditions (i.e., 275 ms). SN: Before Spell Read training, the PMN was attenuated. However, after 40 hours of Spell Read training a robust PMN was apparent in all three incorrect conditions. C) Neuropsychological assessment scores recorded prior to and after 20 hours of Spell Read training.



Results

Control group

A P300 was largest in the correct condition, while the PMN was largest in the Incorrect conditions (Fig. 2).

The PMN showed a frontal distribution, while the P300 showed a parietal distribution.

This pattern of activity was visible in the grand average waveforms and in those of an individual (Fig.2).

PI group

A P300, albeit delayed relative to the control group, differentiated Correct from Incorrect conditions (Fig.3).

The PMN was not shown to differentiate between conditions (Fig. 3).

A delayed/attenuated PMN has been observed in Adolescent PI participants prior to Spell Read training (Fig. 4A).

Participants tested after 20 hour and 40 hours of training showed significant improvements on neuropsychological measures (Table 1).

Changes in the amplitude/onset latency of the PMN are observable after only 20 hours of training (Fig. 4B).

Discussion and Conclusion

The findings supported the hypothesis that the PMN, may serve as a neural marker for phonological processing during spoken word recognition.

The fact that adults with poor phonological skills showed a robust P300, but a reduced PMN, suggests that the current ERP paradigm may be used to assess complex phonemic awareness skills independently of any compensatory strategies used by participants to arrive at the correct answer.

Preliminary evidence of students completing 20 hours of training, shows that neural changes observable in electrophysiological recordings made at the scalp may manifest prior to significant changes on neuropsychological assessments (Fig.4 [SN]).

The combination of neuropsychological and ERP-based assessment methods will unequivocally demonstrate that reading deficits may be remediated through intensive phonological training.

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