Effects of computerized auditory training on rapid auditory processing in young school-aged children: An ERP study

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Rapid auditory processing (RAP) is believed to underlie successful language acquisition, and conversely, impaired RAP is thought to be a causal deficit in language disorders such as Specific Language Impairment (SLI). In this preliminary study, RAP was evaluated in 6.5 – 9 year old SLI children before and after completing a computerized auditory intervention program (Fast ForWord®) that targets slowed or inefficient low-level auditory processing. Age-matched controls with normal language skills received no intervention. Pre- and post- intervention event related potentials (ERPs) were passively elicited in response to a tone pair (100Hz - 100Hz) that occurred with 80% probability in a block of 833 trials. Each tone was 70 ms in duration, and the time between the tones was 70 ms. Inspection of the control group's P1-N1-P2 complex revealed that all three of these components were distinct, peaking at ca. 95, 140, and 160 ms, respectively. This complex was followed by a prominent N2 with a latency of ca. 270 ms. In the pre-intervention SLI group, the N1 and P2 components were undetectable and only the P1 and N2 peaks were visible. However, following intervention, the SLI group exhibited a P1-N1-P2 complex with three identifiable components that resembled that of controls in morphology and latency. No changes were observed in the P1 and N2 peaks. These data suggest that RAP is altered in children with SLI after completing Fast ForWord® such that they are better able to process two rapidly presented, brief, successive tones individually rather than as a single unitary event.

Long-latency obligatory auditory ERP components, such as P1, N1, P2, and N2, have been found to differentiate between SLI children and age matched controls (N1-P2-N2: McArthur & Bishop, 2004) and are sensitive to rate of presentation such that they attenuate and even disappear with fast presentation rates (N1 and P2). These ERP components have been found to decrease in amplitude and latency following language remediation training (P1, P2 and N2: Hays et al., 2003).

Fast ForWord® (FFWD) is a computer based intervention program for individuals with language learning impairments (LLI). FFWD targets

slowed or inaccurate rapid auditory processing that underlies language learning problems through the use of modified speech and adaptive training (Tallal, 2004; Tallal et al., 1996; Merzenich et al., 1996).
Improvements in language and reading skills following FFWD have been reported (Tallal et al., 1996; Merzenich et al., 1996), but descriptions of the neurophysiological changes in auditory processing resulting from FFWD are still scarce (Temple et al., 2003).
• To investigate differences in rapid auditory processing using ERPs:
• between children with LLI and controls
• in children with LLI before and after Fast ForWord® training

Participants

LLI group: 5 children (4 male) with a language-based learning impairment [mean CELF-4 Core Language Standard Score 85.3 (SD 8.2)]. Mean age 8.02 years (SD 0.94) pre-FFWD. Mean age 8.44 years (SD 0.88) post-FFWD.
Control group: 8 children (4 male) with no reported language or learning problems [mean CELF-4 Core Language Standard Score 116.7 (SD 5.6)]. Mean age 8.04 years (SD 0.77).
All LLI and control children were full term, of normal birth weight and had unremarkable post-natal development. All subjects had normal non-verbal IQ scores (WASI Performance IQ >90), no reported hearing problems or other neurological problems.

Stimuli

Complex tones with a fundamental frequency of 100 and 300 Hz with 15 harmonics (6 dB roll-off per octave) and 70 ms duration were paired to create the stimuli presented in an oddball paradigm at 75dB SPL free field via loud speakers to the left and right of the participant.

ERP recording

The EEG/ERP data were recorded with 64 Ag/AgCl electrodes connected within a sensor net (Electrical Geodesics, Inc.).
EOG was recorded with electrodes above, below, and lateral to the eyes.
The EEG electrodes were referred to the vertex electrode, and re-referenced off-line to the averaged (whole head) reference.

Group Effect: LLI (pre-FFWD) and Controlsand

Morphology: In the standard wave, controls exhibited P1-N1-P2 complex and a prominent N2, while LLI children exhibited only a robust P1 and prominent N2.
Amplitude:
• Standard wave: **P1** LLI children > controls children at **left** frontal

channels (F3 and F7). There were no differences in N2 amplitude.
• Deviant wave: **N2** of LLI children > controls at **right** central (C6) and frontotemporal (FT8) channels
Latency:
• Standard wave: **P1** LLI children < controls at the **left** frontal (FZLeft) channel. **N2** LLI children < controls at **left** frontal (F7), central (C5), frontocentral (FC5), and frontotemporal (FT7) channels.
frontotemporal (FT8) channels.
N2 LLI children < controls at **right** frontal (FZRight, F4), central (C6), frontocentral (FC2) and frontotemporal (FT8) channels

Intervention Effect: Pre-Fast ForWord vs. Post-Fast ForWord
Morphology: In standard wave, pre-FFWD: only P1 and N2 visible. Post-FFWD: P1-N1-P2 complex and a prominent N2. Post-FFWD, there was a tighter overlap of the standard and deviant waves.
Amplitude:
• Standard wave: **P1** pre-FFWD > post-FFWD at FC1 & C2.
P2 pre-FFWD > post-FFWD at right frontal (F3)
frontocentral (FCZ, FC1, FC2), central (C2).
P2 pre-FFWD < post-FFWD at parietal (PZ) channel.
• Deviant wave: no significant changes
Latency: No significant changes in standard or deviant wave.

These findings suggest that:
• ERP waveforms of LLI children prior to intervention exhibit greater amplitude and shorter latencies than controls.
• Following FFWD, there is an overall decrease in the amplitude of LLI waveform components, resulting in more overlap of standard and deviant waves
• Post-FFWD, the P1-N1-P2 complex of LLI children was visible and similar to that of controls suggesting alterations in the processing of rapidly presented, transient auditory stimuli.

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Acknowledgements
N1
P2
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