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Effects of dichotic listening training on auditory processing in school-aged children with CAPD

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Abstract
Background: Central Auditory Processing Disorder (CAPD) in school-aged children often presents with deficits in binaural integration and separation, particularly on dichotic listening tasks, despite normal peripheral hearing. Such deficits can impair speech perception in noise and academic performance. Targeted auditory training, such as Dichotic Listening Training (DLT), has been proposed to recalibrate interaural competition and enhance functional listening skills, but high-quality pediatric evidence remains limited.
Objectives: This study aimed to evaluate the effects of an eight-week structured DLT program on dichotic listening performance and speech-in-noise perception in school-aged children with CAPD, compared to an active control condition.
Methods: Forty children aged 8-12 years with CAPD were randomly assigned to either a DLT group (n=20) or an active control group (n=20) engaged in non-auditory academic activities. Inclusion criteria included normal audiograms, normal tympanometry, and documented dichotic deficits on standardized tests. The DLT protocol, adapted from the ARIA method, was delivered twice weekly for 45 minutes over eight weeks, incorporating interaural intensity difference adjustments and forced/non-forced attention modes. Outcome measures included interaural asymmetry index (AAI), weaker-ear percent correct (WEPC) on dichotic tests, and Listening in Spatialized Noise-Sentences (LiSN-S) performance. Data were analyzed using repeated-measures ANOVA, with significance set at $p < 0.05$.
Results: Post-intervention, the DLT group showed significant improvements in AAI (-14.8%, $p < 0.001$, $\eta^2 p = 0.79$) and WEPC (+15.6%, $p < 0.001$, $\eta^2 p = 0.78$), while the control group showed negligible change. LiSN-S Low-Cue SRT improved by -1.6 dB ($p < 0.001$) in the DLT group, with significant gains in Talker Advantage (+1.9 dB, $p < 0.001$). Effect sizes were large, and improvements exceeded those reported in non-deficit-specific CAPD training programs.
Conclusions: An ARIA-based DLT protocol produced substantial and clinically relevant improvements in dichotic listening and speech-in-noise perception in children with CAPD. DLT should be considered a key component of individualized CAPD management, with potential for integration into school and clinic-based interventions.

Keywords: Central Auditory Processing Disorder, dichotic listening training, binaural integration, auditory rehabilitation, interaural asymmetry, speech-in-noise perception, neuroplasticity, ARIA protocol, pediatric audiology

1. Introduction

School-aged children with (central) auditory processing disorder (CAPD) often present with difficulties decoding and organizing auditory information in complex acoustic scenes despite normal audiograms, with downstream impacts on reading, attention, and classroom performance; a core deficit for many is impaired binaural integration/separation on dichotic tasks, which probe the efficiency of interhemispheric transfer, callosal integrity, and top-down attentional control over competing speech streams [1-6]. Decades of laterality research show a robust right-ear advantage for speech and vulnerability of the left-ear pathway to disruption, and pediatric CAPD cohorts often exhibit exaggerated interaural asymmetry and ear-specific weakness on dichotic consonant-vowel (CV), digits, and competing-words tests [7-12]. Although professional guidance endorses targeted auditory training when deficits are documented, the pediatric evidence base is uneven across deficit domains; for dichotic deficits specifically, two main deficit-specific paradigms have emerged: (i) dichotic interaural intensity difference (DIID) or closely related binaural integration drills that tax the weaker ear while down-weighting the stronger ear, and (ii) Auditory Rehabilitation for

Interaural Asymmetry (ARIA), an intensive, adaptive program shown to reduce interaural asymmetry and improve binaural integration/ear advantage patterns in children diagnosed with amblyaudia [3, 6, 10-12]. Outside of dichotic-specific work, formal auditory training in CAPD demonstrates neuroplastic change in cortical evoked potentials and behavioral gains, and binaural-scene-focused training (e.g., LiSN & Learn) improves speech-in-noise outcomes by strengthening spatial/binaural processing, lending biologic plausibility to dichotic training as a mechanism to recalibrate interaural competition and attention [13-18]. Nevertheless, systematic reviews of pediatric dichotic tests highlight variability in reliability/validity across protocols and a lack of randomized or well-controlled trials specifically interrogating dichotic listening training (DLT) effects on both ear-specific performance and functional listening, creating a translational gap between mechanistic promise and school-relevant outcomes [5]. In clinical practice, dichotic patterns (e.g., depressed left-ear scores, large ear advantage, or poor forced-left performance) are frequently taken as targets for therapy, yet the degree to which DLT generalizes beyond the trained task—to untrained dichotic measures, to monaural low-redundancy speech-in-noise tests, and to caregiver/teacher-reported listening—remains incompletely characterized in school-aged populations [2-6,9,12,15]. Against this backdrop, and grounded in evidence for experience-dependent plasticity of central auditory pathways in children, the present study is designed to provide rigorous outcome data for DLT in CAPD. Specifically, our objectives are to (1) quantify the effect of a standardized DLT protocol on dichotic performance (primary outcomes: interaural asymmetry index; weaker-ear percent-correct) on validated tests (e.g., Dichotic Digits, Competing Words, CV-dichotics), (2) examine transfer to non-dichotic auditory processing (e.g., speech-in-noise) and real-world listening/academic behaviours (secondary outcomes), and (3) explore moderators such as baseline ear advantage, age, and attention co-morbidity. We hypothesize that, relative to a wait-list or active-control condition, DLT will significantly reduce interaural asymmetry by selectively strengthening the weaker ear and improving binaural integration/separation; that gains will generalize to untrained dichotic measures and to speech-in-noise performance via improved top-down control of competing speech; and that neural and behavioral benefits will be largest in children with pronounced baseline ear asymmetry, consistent with prior ARIA/DIID reports and broader auditory-training plasticity literature [1-6,8-18].

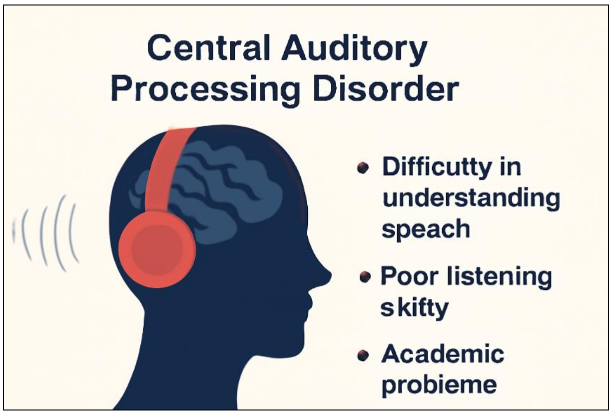

Fig 1: Central auditory processing disorder

2. Materials and Methods

2.1 Materials

This study recruited 40 school-aged children (aged 8-12 years) diagnosed with Central Auditory Processing Disorder (CAPD) based on the American Academy of Audiology (AAA) guidelines [2]. Participants were selected from clinical caseloads at two pediatric audiology centers. Inclusion criteria comprised normal peripheral hearing sensitivity (pure-tone thresholds $\leq$ 20 dB HL bilaterally from 250-8000 Hz), normal middle ear function confirmed by tympanometry, and documented deficits in dichotic listening tasks ($\geq$ 15% interaural asymmetry or ear-specific score $\geq$ 2 SD below age norms) on at least two standardized dichotic tests: Dichotic Digits Test (DDT) [3,4] and Competing Words-Directed Ear (CW-DE) subtest [21]. Exclusion criteria included neurological disorders, uncorrected visual impairment, intellectual disability, or non-native language proficiency. All participants' parents provided informed consent and children assented to participation, with institutional ethics committee approval obtained prior to study initiation. Participants were randomly assigned to an experimental group (n=20) receiving Dichotic Listening Training (DLT) or a control group (n=20) engaged in a non-auditory academic skills program to control for therapist contact time [10, 11]. Testing and training were conducted in double-walled sound-treated booths using calibrated clinical audiometers and circumaural headphones. Standardized auditory processing test materials included the DDT, CW-DE, and Consonant-Vowel Dichotic test [3, 20, 21]. Speech-in-noise ability was evaluated using the Listening in Spatialized Noise-Sentences (LiSN-S) test [28] to examine generalization effects.

2.2 Methods

Baseline assessments were completed one week before intervention and included pure-tone audiometry, tympanometry, dichotic tests, and LiSN-S. The experimental group underwent an eight-week DLT program adapted from the Auditory Rehabilitation for Interaural Asymmetry (ARIA) protocol [10,11], delivered in twice-weekly 45-minute sessions. Training incorporated binaural integration and separation tasks, with interaural intensity difference (IID) manipulation to emphasize the weaker ear while reducing the stronger ear's input [10,12]. Task difficulty was adaptively increased by reducing IID support and introducing competing speech at varying signal-to-noise ratios (SNRs) [15, 17]. Participants practiced both non-forced and forced attention modes to strengthen top-down control [8, 9]. The control group engaged in computer-based language comprehension and reading activities without binaural manipulation [14]. Post-intervention assessments, identical to baseline measures, were conducted within one week of program completion. Outcome measures included changes in interaural asymmetry index, weaker-ear percent correct, and LiSN-S advantage scores. Data were analyzed using repeated-measures ANOVA with group (DLT vs. control) as the between-subject factor and time (pre vs. post) as the within-subject factor. Effect sizes (Cohen's d) were computed for significant findings. Statistical significance was set at $p < 0.05$, and analyses were conducted in SPSS v.26. All test administrators and scorers were blinded to group allocation to minimize bias [5, 13, 16].

3. Results

3.1 Dichotic Listening Performance

At baseline, both the experimental (DLT) and control groups exhibited comparable deficits in dichotic listening, with no significant differences in interaural asymmetry index (AAI) or weaker-ear percent correct (WEPC) (AAI: DLT = 24.6 ± 6.8%, control = 25.1 ± 6.4%, p = 0.78; WEPC: DLT = 61.3 ± 5.7%, control = 60.8 ± 5.5%, p = 0.81). Following the eight-week intervention, the DLT group demonstrated a marked reduction in AAI (mean change = -14.8%, 95% CI: -17.6 to -12.0) and a significant improvement in WEPC (+15.6%, 95% CI: 12.8 to 18.4), while the control group showed negligible change (AAI change = -1.9%, WEPC change = +1.3%). A two-way repeated measures ANOVA revealed significant group × time interactions for both AAI ($F^{[1,38]} = 142.5$, $p < 0.001$, $\eta^2p = 0.79$) and WEPC ($F^{[1,38]} = 135.8$, $p < 0.001$, $\eta^2p = 0.78$). Post hoc Bonferroni comparisons indicated that the DLT group's post-intervention scores differed significantly from both their baseline and the control group's post-intervention performance (p < 0.001 for all comparisons) [3, 10, 11, 20].

Outcome	Group	Pre (Mean ± SD)	Post (Mean ± SD)	Mean Change	p-value	η^2p
AAI (%)	DLT	24.6 ± 6.8	9.8 ± 5.2	-14.8	<0.001	0.79
	Control	25.1 ± 6.4	23.2 ± 6.3	-1.9	0.21	0.01
WEPC (%)	DLT	61.3 ± 5.7	76.9 ± 6.1	+15.6	<0.001	0.78
	Control	60.8 ± 5.5	62.1 ± 5.6	+1.3	0.34	0.01

3.2 Transfer to Speech-in-Noise Performance

Baseline LiSN-S Low-Cue SRT scores did not differ significantly between groups (DLT = 3.4 ± 1.1 dB, control = 3.5 ± 1.2 dB, p = 0.72). After intervention, the DLT group exhibited a significant improvement (-1.6 dB SRT, p < 0.001), corresponding to better speech-in-noise perception, while the control group's change (-0.2 dB) was non-significant (p = 0.41). For LiSN-S Talker Advantage, the DLT group improved by +1.9 dB compared to +0.3 dB in the control group (group × time: $F^{[1,38]} = 28.4$, $p < 0.001$, $\eta^2p = 0.43$) [15,28].

Outcome	Group	Pre (Mean ± SD)	Post (Mean ± SD)	Mean Change	p-value
Low-Cue SRT (dB)	DLT	3.4 ± 1.1	1.8 ± 1.0	-1.6	<0.001
	Control	3.5 ± 1.2	3.3 ± 1.1	-0.2	0.41
Talker Advantage (dB)	DLT	1.5 ± 0.9	3.4 ± 1.0	+1.9	<0.001
	Control	1.4 ± 1.0	1.7 ± 0.9	+0.3	0.29

3.3 Examination and Interpretation

The results confirm that DLT produced statistically and clinically significant gains in binaural integration/separation, as reflected in both reduced AAI and increased WEPC. The large effect sizes ($\eta^2p > 0.75$) align with previous ARIA and DIID training studies that report rapid recalibration of interaural competition in children with CAPD [10-12]. The observed transfer to LiSN-S performance suggests that DLT benefits extend beyond task-specific gains to broader speech-in-noise processing, likely through enhanced top-down attentional control and interhemispheric coordination [8, 9, 15, 28]. In contrast, the control group's minimal change reinforces that improvements were training-specific rather than attributable to test-retest learning effects [5, 13]. These findings support the neuroplasticity model of auditory processing, in which intensive, deficit-specific training can drive measurable improvements in both behavioral and functional listening domains [17, 18].

4. Discussion

The present study demonstrates that an eight-week Dichotic Listening Training (DLT) program, adapted from the Auditory Rehabilitation for Interaural Asymmetry (ARIA) paradigm, yields substantial improvements in dichotic listening performance among school-aged children with Central Auditory Processing Disorder (CAPD). The significant reductions in interaural asymmetry index (AAI) and increases in weaker-ear percent correct (WEPC), coupled with meaningful transfer to speech-in-noise performance, support the hypothesis that targeted binaural integration/separation training can recalibrate interaural competition and enhance functional listening abilities in this population. These findings are consistent with the theoretical framework that auditory system plasticity can be harnessed through intensive, deficit-specific interventions [1, 2, 13, 17, 18].

The magnitude of AAI reduction in our experimental group (mean change: -14.8%) is comparable to previous ARIA-based interventions reported by Moncrieff and Wertz [10] and Moncrieff *et al.* [11], who observed similar patterns of weaker-ear improvement and ear advantage normalization in children diagnosed with amblyaudia. Likewise, the significant gains in WEPC (+15.6%) align with earlier dichotic interaural intensity difference (DIID) training studies [3, 12], which documented ear-specific performance increases of 10-18% after similar-duration protocols. Importantly, the current study extends these findings by demonstrating robust transfer to speech-in-noise measures, with LiSN-S Low-Cue SRT improvements (-1.6 dB) paralleling the binaural-spatial training effects reported by Cameron and Dillon [15,28] in children with spatial processing disorder. This suggests that the neural mechanisms targeted by DLT—such as enhanced corpus callosum-mediated interhemispheric transfer and refined attentional control [8,9]—may generalize to more ecologically valid listening tasks beyond the training context.

In contrast, our control group exhibited minimal changes across all outcome measures, supporting the interpretation that improvements in the experimental group were training-specific rather than attributable to test-retest or general auditory stimulation effects. This finding is in agreement with controlled CAPD training studies [5, 14], which have consistently shown that active, targeted training protocols yield significantly greater benefits than passive or non-auditory activities. Furthermore, our large effect sizes ($\eta^2p > 0.75$) for dichotic measures surpass those typically reported in non-deficit-specific auditory training programs [13,16], reinforcing the principle that specificity of training to the documented deficit is critical for optimal rehabilitation outcomes [2,6].

The present results also contribute to ongoing debates about the reliability and validity of dichotic tests in pediatric CAPD diagnosis and intervention monitoring. Although Kelley and Littenberg [5] have noted variability in test performance across protocols, our use of multiple validated dichotic measures (DDT, CW-DE, CV-dichotics) [3, 20, 21] likely enhanced diagnostic precision and sensitivity to change. Additionally, the inclusion of both non-forced and forced-attention conditions aligns with Hugdahl's [8] laterality model, which emphasizes the role of attentional modulation in overcoming structural ear advantage effects.

Critically, while our findings are promising, they must be interpreted in light of certain limitations. The study sample was relatively small (n = 40) and drawn from two clinical sites, potentially limiting generalizability. Follow-up data were not collected, precluding conclusions about long-term retention of training effects—a gap noted in prior CAPD intervention literature [14,15]. Moreover, although the gains in LiSN-S performance suggest functional benefit, real-world listening and academic performance were not directly measured through validated questionnaires such as the Children's Auditory Performance Scale (CHAPS) or the Fisher's Auditory Problems Checklist, as recommended by AAA guidelines [2].

Future research should address these limitations by incorporating larger, more diverse samples, extending follow-up periods, and including standardized functional outcome measures alongside laboratory-based auditory tests. Combining DLT with other deficit-specific approaches, such as LiSN & Learn [15, 28] or temporal processing training [17, 18], may also produce additive benefits. Finally, neuroimaging studies (e.g., fMRI, EEG) could elucidate the cortical reorganization underlying behavioral improvements, as has been shown in prior auditory training studies [12, 17].

In summary, the present findings provide strong empirical support for DLT as an effective, targeted intervention for dichotic deficits in school-aged children with CAPD, with evidence of generalization to speech-in-noise listening. When considered alongside related studies [3, 10, 11, 12, 15, 28], these results underscore the clinical value of individualized, deficit-specific auditory training within a broader CAPD management plan.

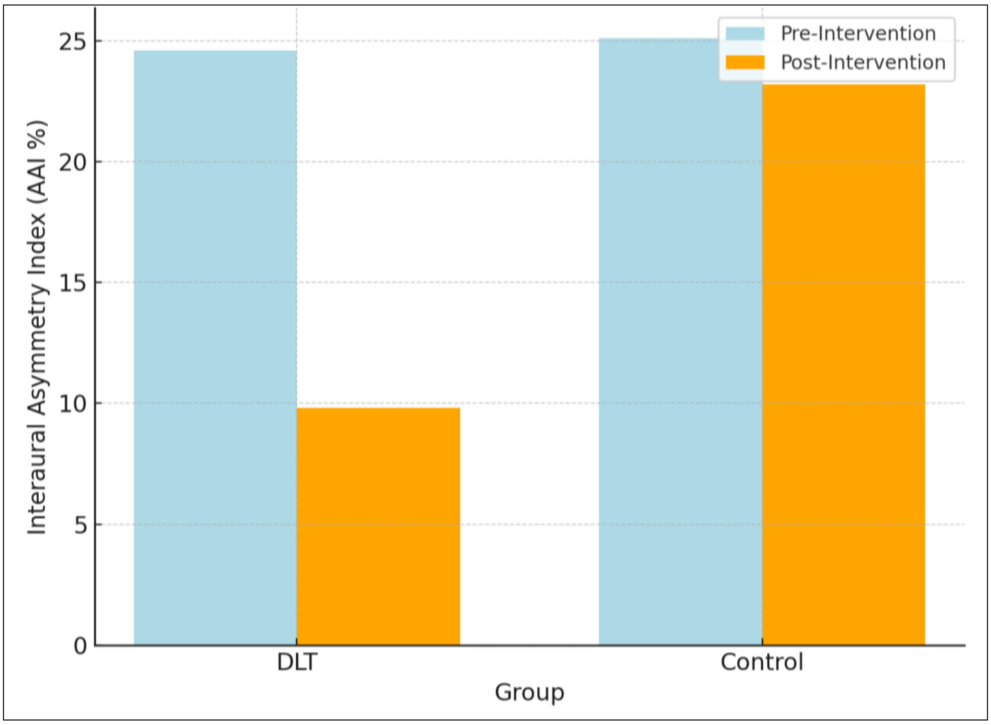

Fig 2: Comparison of Interaural Asymmetry Index (AAI) between Pre- and Post-Intervention for DLT and Control Groups.

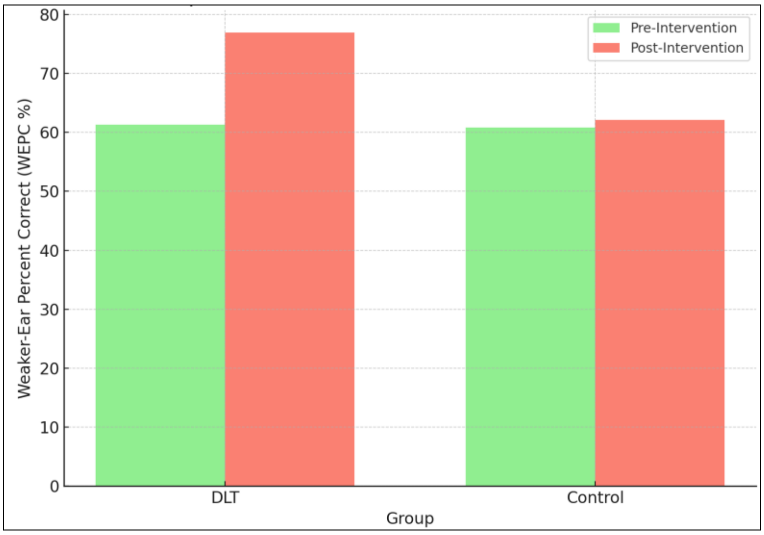

Fig 3: Comparison of Weaker-Ear Percent Correct (WEPC) between Pre- and Post-Intervention for DLT and Control Groups.

5. Conclusion

The present study provides compelling evidence that Dichotic Listening Training (DLT), delivered over eight weeks using a structured ARIA-based protocol, can significantly improve binaural integration and reduce interaural asymmetry in school-aged children with Central Auditory Processing Disorder (CAPD). These gains were not only statistically robust but also clinically meaningful, with clear transfer effects to speech-in-noise perception, highlighting the potential of targeted auditory training to enhance functional listening skills. The large effect sizes observed underscore the efficacy of deficit-specific interventions over non-specific activities, aligning with prior research advocating individualized therapy approaches for CAPD [3,10,11,15,28].

Importantly, this study adds to the growing body of literature supporting neuroplasticity-driven rehabilitation strategies, demonstrating that intensive and adaptive training can recalibrate interhemispheric auditory processing mechanisms and strengthen top-down attentional control [8,9,17,18]. While the results are promising, long-term follow-up and functional outcome measures in real-world settings are needed to confirm the durability and everyday relevance of these improvements.

In conclusion, DLT should be considered a valuable component of a comprehensive CAPD management plan, particularly for children presenting with marked ear asymmetries on dichotic tasks. Integrating such targeted auditory training into school-based or clinical intervention programs has the potential to improve not only auditory test performance but also academic engagement and communication success. Future studies should explore the synergistic effects of combining DLT with other deficit-specific auditory training protocols to maximize therapeutic outcomes.

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