Skull Bone and Paranasal Sinus Acoustics in Dyslexia: A Narrative Review of Passive Hearing, Resonance, and Phonological Processing

Prepared as a review-article draft for ENOSH Science Journal

Proposed article type: Review Article

Focus Area	Dyslexia, acoustics, passive hearing
Source Basis	Narrative synthesis of the uploaded POMA article
Intended Outlet	ENOSH Science Journal

Abstract

Dyslexia is commonly studied as a disorder of phonological processing, reading fluency, and decoding, with most research emphasizing central auditory and neural mechanisms. However, emerging discussion has raised the possibility that peripheral and craniofacial acoustic factors may also contribute to atypical auditory processing in some children. This narrative review examines the concept that skull bone conduction and paranasal sinus resonance may influence passive hearing and fine auditory discrimination relevant to phonological development. The review synthesizes the acoustic rationale, measurement logic, and clinical interpretations reported in the source paper on dyslexic children, including damping, resonance shifts, and rumbling abnormalities observed across frontal, maxillary, and mastoid regions. The reviewed evidence suggests that cranial cavity acoustics may represent an underexplored component in the broader sensory profile of dyslexia. At the same time, current evidence remains preliminary, with important limitations such as small samples, the lack of matched controls, and limited imaging confirmation. This review argues that skull and sinus acoustics deserve further interdisciplinary investigation, not as a replacement for established cognitive and neural models of dyslexia, but as a complementary biomechanical dimension that may refine early screening and deepen understanding of auditory heterogeneity in neurodevelopmental disorders.

Keywords

Dyslexia; passive hearing; skull bone resonance; paranasal sinuses; phonological processing; bone conduction; auditory processing

Key Review Themes

Theme	Main Insight	Why It Matters
Peripheral acoustics	Skull and sinus cavities may shape passive sound transmission in ways not captured by traditional ear-only models.	Broadens the auditory-processing discussion in dyslexia.
Rumbling abnormality	Low-frequency rumbling was reported as the most prominent abnormal pattern in the source study.	Suggests a potentially distinctive acoustic phenotype worth validating.
Lateralization	Right-sided abnormalities were more frequent than left-sided abnormalities.	Connects resonance findings with broader laterality questions in dyslexia.
Methodological caution	The evidence is exploratory because the sample is small and lacks a matched control group.	Prevents over-interpretation and frames realistic next

		steps.

1. Introduction

Dyslexia is a specific learning disorder characterized by persistent difficulties in accurate reading, spelling, fluency, and decoding. The source article places these reading-related difficulties within a wider auditory-processing context, noting that deficits in auditory frequency discrimination, amplitude-modulation perception, stream segregation, and spatial sound processing have all been discussed in the dyslexia literature. Most prior work, however, has focused on cortical, brainstem, and central auditory explanations, while relatively little attention has been given to peripheral or craniofacial acoustic pathways.

Within this context, skull bone structure and paranasal sinus cavities represent a provocative but underexplored biomechanical substrate. If cranial resonance affects how broadband sound is transmitted, filtered, or transformed before or alongside conventional auditory processing, then some part of the sensory variability seen in dyslexia may involve more than central neural coding alone. This review therefore revisits dyslexia through an acoustic lens and asks whether passive hearing through skull and sinus resonance deserves a place in the broader explanatory framework.

2. Dyslexia and the Auditory Processing Debate

A major contribution of the source paper is that it situates skull resonance within the existing auditory-processing debate instead of presenting it as an isolated claim. The paper reviews literature showing that many dyslexia studies have emphasized sensory perception, especially auditory and visual pathways, but also notes that this evidence remains incomplete in explaining the full basis of reading difficulty. In conventional models, phonological deficits, timing abnormalities, and cortical processing differences dominate the discussion. By contrast, the influence of skull and sinus anatomy on passive sound conduction has largely been overlooked.

This gap matters because phonological processing depends not only on language representation, but also on the fidelity, timing, and spectral quality of incoming auditory information. Even subtle distortions in passive sound transmission could theoretically alter low-level acoustic cues before they are interpreted by higher neural systems. The reviewed evidence does not yet prove such a pathway, but it makes a credible case that the question warrants systematic study.

3. Skull Bone and Sinus Resonance as an Acoustic System

The source study frames the skull and paranasal cavities as an acoustic system rather than merely an anatomical background. Using cavity size data drawn from earlier imaging studies, the authors estimated resonance frequencies for frontal, maxillary, and mastoid regions across age and sex categories. Their logic rests on the idea that resonance behavior varies with cavity volume, opening area, and effective port length, making skull and sinus structures potentially relevant to passive hearing.

This shift in framing is important. Instead of asking only whether dyslexia involves hearing deficits in a conventional clinical sense, the reviewed work asks whether the craniofacial system itself may shape sound transmission in a way that contributes to phonological vulnerability. That move broadens the field of inquiry and helps define a niche for acoustics within neurodevelopmental research.

4. Evidence from Passive Hearing Measurements in Dyslexic Children

The empirical basis reviewed here comes from a cross-sectional study of 30 children with dyslexia, aged 6 to 14 years. Participants were tested in a sound-isolated RC25 room using broadband Gaussian noise, with two air-conduction microphones placed near the external ear canal openings and six bone-conduction microphones positioned over frontal, maxillary, and mastoid regions. Signal acquisition was performed at 48 kHz with 24-bit resolution, and the recorded data were analyzed using STFT with a Hanning window and a high-overlap setting.

The main result was that 73.3% of the dyslexic sample showed abnormal passive sound-conduction patterns. The study organized these abnormalities into three acoustic categories: damping, resonance shifts, and rumbling. Rumbling emerged as the most prominent abnormal pattern, while right-sided abnormalities were more frequent than left-sided abnormalities. Taken together, these findings suggest that passive hearing abnormalities may not be random and may instead follow recognizable acoustic profiles.

5. Interpreting Damping, Resonance Shifts, and Rumbling

The classification into damping, resonance, and rumbling is one of the most conceptually useful features of the source paper. Damping is discussed as potentially consistent with fluid accumulation, sinusitis, or other conditions that increase attenuation. Resonance shifts are interpreted as possible consequences of altered cavity geometry or port dimensions. Rumbling is presented as a more complex pattern that could emerge from mucosal thickening, rough cavity surfaces, septa, or coupled-resonator behavior.

As a review point, this classification is promising because it offers a preliminary acoustic vocabulary for describing cranial resonance abnormalities in dyslexia. However, these categories remain interpretive constructs rather than confirmed pathophysiological entities, because the reviewed study did not directly validate each abnormality type using imaging within the same participants.

6. Lateralization and Sex Differences

The source study also reported sex-related and lateralized patterns. Males constituted the larger share of the abnormal group, and right-sided abnormalities were more frequent and statistically more prominent than left-sided abnormalities. The discussion linked these observations to broader evidence on the higher prevalence of dyslexia in males, sex-related anatomical variability, and historical theories of dyslexic lateralization.

These observations are valuable because they suggest that skull resonance may not be uniformly distributed across the cranial system. If confirmed in larger studies, lateralization could become one of the most informative aspects of resonance-based assessment. At present, however, it remains unclear whether the right-sided predominance reflects dyslexia-specific biology, developmental asymmetry, sinus pathology, or sample-specific effects.

7. Methodological Limitations

The source article is appropriately transparent about its limitations. The sample size was relatively small, no matched control group of typically developing children was included, direct neuroimaging comparison was not performed within the same participants, and high-resolution CT confirmation of anatomical variations was not available. Potential confounders such as allergic rhinitis were also not systematically excluded.

These limitations have direct implications for interpretation. The current evidence supports plausibility and hypothesis generation, but it does not yet establish specificity, diagnostic validity, or causality. For that reason, the most defensible interpretation is that skull and sinus acoustics may form one component of auditory heterogeneity in dyslexia rather than a standalone explanation.

8. Future Research Directions

The next phase of research should integrate acoustic measurement with imaging, language assessment, audiological profiling, and longitudinal design. Future studies should include matched control groups, explicit reliability testing for abnormality classification, and direct anatomical confirmation of sinus morphology and cavity conditions. It would also be useful to test whether damping, resonance-shift, and rumbling profiles correlate with distinct reading outcomes, phonological subtypes, or intervention response.

If later studies confirm stable and clinically relevant associations, skull resonance profiling might become a low-cost adjunct tool for subgroup characterization or early screening. At present, however, its most valuable role is as an interdisciplinary research hypothesis linking acoustics, pediatrics, anatomy, and neurodevelopment.

9. Conclusion

The literature reviewed here suggests that passive sound conduction through skull bone and paranasal sinus structures may represent a neglected dimension of auditory processing in dyslexia. The available evidence indicates that damping, resonance shifts, and rumbling abnormalities can be detected in a substantial proportion of dyslexic children in at least one exploratory study, with notable right-sided predominance. At the same time, the evidence base remains preliminary and methodologically constrained. The most balanced conclusion is therefore not that skull resonance explains dyslexia, but that cranial acoustic behavior may form part of a broader sensory profile deserving serious investigation. This perspective expands the conversation around dyslexia and encourages a more integrated model in which cognition, neural processing, anatomy, and acoustics are studied together.

References

Noshokaty, I. Y., Elgebaly, H. H., & Omar, M. M. (2025). Passive hearing abilities of dyslexia children: Investigating the rumble frequency of skull bones cavity. Proceedings of Meetings on Acoustics, 55, 015003. https://doi.org/10.1121/2.0002025

American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders (5th ed.).

Calcus, A., Lorenzi, C., Collet, G., Colin, C., & Leybaert, J. (2018). The role of auditory processing in developmental dyslexia. Neuropsychologia, 117, 629–644.

Kitamura, T., Takemoto, H., Makinae, H., Yamaguchi, T., & Maki, K. (2017). Acoustic analysis of detailed three-dimensional shape of the human nasal cavity and paranasal sinuses. Interspeech.

Moncrieff, D. W., & Black, J. R. (2008). Dichotic listening deficits in children with dyslexia. Dyslexia, 14(1), 54–75.

Papadopoulou, A. K., Vlachos, F., & Papadatou-Pastou, M. (2022). Cerebral lateralization of language in children at risk for dyslexia: A review of neuroscientific evidence. Dialogues in Clinical Neuroscience & Mental Health, 5(2), 89–97.

Smith, J. O. (2011). Spectral audio signal processing. W3K Publishing.

Plumbley, M. D., Wang, D., Ellis, D. P. W., Tzanetakis, G., & Virtanen, T. (2010). Time-frequency analysis techniques in speech and audio processing. IEEE Signal Processing Magazine, 27(6), 32–41.

Yamakawa, K., Nishijima, H., Koizumi, M., & Kondo, K. (2024). Assessing volume growth of paranasal sinuses and nasal cavity in children using three-dimensional imaging software. Auris Nasus Larynx, 51(6), 917–921.

Arnett, A. B., Pennington, B. F., Peterson, R. L., Willcutt, E. G., DeFries, J. C., & Olson, R. K. (2017). Explaining the sex difference in dyslexia. Journal of Child Psychology and Psychiatry, 58(6), 719–727.