Volume-13/Issue-II/Dec. 2025/ISSN No.-2321-3450

ORIGINAL RESEARCH ARTICLE

DOI: htttp: /doi.org/10.36611/upjohns/volume13/Issue2/4
Date received: 14.11.2025 / Date Published : 31.12.2025

INVESTIGATION OF AUDITORY TEMPORAL PROCESSING ABILITY IN DYSLEXIC CHILDREN

Author: Seyede Farank Emami

Authors Affiliation: Associate Professor, Hearing Disorders Research Center, Department of Audiology, Faculty of Rehabilitation, Hamadan University of Medical Sciences. Hamadan, Iran.

ABSTRACT

INTRODUCTION

Dyslexia is a type of reading disability characterized by reading deficits and inadequate oral language skills. The aim of this study was to investigate the auditory temporal processing ability in dyslexic children and compare it with normal children.

MATERIALS AND METHODS

This study was cross-sectional and comparative. The study population was 25 normal children aged 8 to 10 in elementary school. The sample size included 25 dyslexic and normal children in the same age range. Data collection tools included history taking using a questionnaire, otoscopic examination, immittance audiometry, pure tone audiometry, and gap-in-noise detection test (GAP-N). The Mann-Whitney test was used to analyze the data and compare the mean and standard deviation of the groups.

RESULTS

The mean and standard deviation of the GAP-N threshold for dyslexic children was 8.6 ± 0.8 and 5.1 ± 0.06 for normal children. The percentage of GAP-N for dyslexic children was 50.4 ± 0.3 and 64.7 ± 0.5 for normal children. A significant difference was observed between the mean GAP-N threshold for dyslexic and normal children (Pv = 0.001), and the difference in the mean percentage of GAP-N for dyslexic children compared to normal children was significant (Pv = 0.001).

CONCLUSION

Dyslexic children are weaker in auditory temporal processing than normal children, and since the temporal processing and separation of sounds plays an important role in speech perception, dyslexia is expected to cause deficits in comprehension/production, reading, and writing skills.

KEYWORDS

Hearing, Temporal Processing, Dyslexia, Auditory Temporal Processing and Dyslexia

INTRODUCTION

Dyslexia is a type of learning disability in which a person has difficulty recognizing and reading, writing, and learning words (1). Dyslexia can manifest as a problem with phonetics, decoding, dictation, auditory skills, short-term memory, or rapid naming (2). It is not caused by a disorder in the intelligence quotient (IQ) and educational opportunities (3-1). Neural, genetic, and environmental interactions play a role in the development of the lesion (1, 2). Due to lack of recognition of the lesion, many affected children are considered mentally retarded (4), even though they have normal intelligence and no visual impairment (3).

The most common symptom is the child's very poor spelling and a tendency to write more or less letters when writing words (5). People with dyslexia may have symptoms such as avoiding reading and writing, difficulty remembering and recalling, inability to pronounce and process words, spelling, and spending a long time reading and writing (4, 5). These problems may persist into adulthood, and the person may have symptoms such as difficulty reading and math, summarizing stories, pronunciation, and avoiding reading activities (1, 2). These people have difficulty understanding terms or committing something to memory (3). Learning a new language is a daunting and time-consuming task for people with dyslexia (2).

A student with dyslexia rarely shows symptoms that can be treated before entering school (5). However, symptoms such as delayed speech, delayed learning of nursery rhymes, and slowness in remembering colors and numbers indicate a learning delay (1-3). After the child enters school, teachers should carefully examine the student's symptoms and learning path. For example, the problem of mirror writing or reverse writing, in which words, letters, and numbers are written in reverse and like a mirror (2).

The presence of a hereditary history is one of the most important cases that can be used to diagnose the individual's condition more quickly (4). Teachers should be careful in examining the symptoms when students enter school. Treatment of those affected can be done in two ways: by parents or by teachers (1). However, what is important at first is the diagnosis and treatment strategy of the counselor, and after ensuring the student's normal intelligence, treatment should be started with the help of parents and teachers (2,4). Given that dyslexia is a lifelong disorder, it cannot be considered a definitive treatment, but with attention, steps can be taken to reduce this problem (5). What makes the treatment of dyslexia effective are educational techniques. Tactile, visual, and auditory techniques are among these techniques that help children with reading skills (1, 4). The affected individual can gradually cope with this disorder by attending private classes with their teachers and taking advantage of their help (1). Parents should also help their child with support, gaining awareness, early diagnosis, monitoring symptoms, encouraging the child to study, communicating with the school, practicing and talking with the child, and referring to counseling and treatment centers for learning disorders (5). Studies show that temporal processing of phonemes is not performed correctly in affected individuals. A phoneme or syllable is the smallest phonetic unit of speech that is created by combining one or two consonants and one vowel, for example, the word mama which has two phonemes: /ma/, /ma/) (3). Temporal processing is a mechanism during which short-term and rapid consecutive sounds are processed and is very important in speech perception, music, social communication, language functions and reading skills (1, 2). It seems that disruption in auditory processing in the central auditory pathway causes disruption in phonological processing. In other words, poor encoding of speech inputs in the afferent auditory pathway causes improper perception of speech sounds and ultimately disruption in phonological processing (1-3). It seems necessary to examine the functioning of the central auditory processing system in these children (1).

One of the common causes of dyslexia is the impairment of the ability to process sounds (speech and non-speech) that occurs in a short or rapid period of time (2). According to the auditory temporal deficit hypothesis; at least one subgroup of dyslexic children has a problem processing fast sound stimuli (1, 3). Phonological processing problems arise due to disruption of the linguistic processing of auditory cortical areas at the lexical and sub-lexical levels (2). From this point of view, defects that occur in the auditory processing of the afferent auditory pathway can be associated with phonological processing disorders, but they are not a cause for the development of this disorder and do not play an important role in the development of dyslexia (1).

The ability of students to process and analyze linguistic sounds can affect the quality of reading development and the transfer of linguistic sounds into written form (6). Decoding a speech signal involves analyzing its acoustic, phonetic, phonological, lexical, syntactic, and semantic components (4, 6). The main components of sound, including frequency, intensity, and time, must be properly processed by the auditory system (2, 3). People who have difficulty perceiving speech will also have difficulty perceiving phonemes (3). This ability, called phonological awareness, is essential for the individual to be able to decode the alphabetic system in which words are made up of combinations of phonemes (2, 3). Therefore, learning this ability is essential for learning how to read (4). The ability of auditory temporal discrimination is very effective in speech perception, such that any disruption in temporal discrimination causes speech perception disorders (5, 6). Therefore, the aim of this study was to investigate the ability of auditory temporal processing in dyslexic children and compare it with normal children.

MATERIALS AND METHODS

In this cross-sectional-comparative research, the study population consisted of normal children aged 8 to 10 years old in elementary school, and the sample size consisted of children with dyslexia in the same age range as normal children. The diagnosis of dyslexic children was based on teacher assessments, school counselor approval, and specialized evaluation by psychologists and speech therapists. Data collection tools included questionnaires, pure tone audiometry, immittance audiometry (tympanometry + ipsilateral and contralateral acoustic reflexes), and GAP-N. The sampling method for normal children was simple random sampling from primary schools for girls and boys based on the inclusion criteria. For dyslexic children, convenience sampling was used. Based on the research conducted, 25 people were selected in each group (7-9) and children were included in the study with the informed consent of their parents or guardians.

The inclusion criteria included age range of 8 to 12 years, normal hearing thresholds, normal intelligence, no developmental/ behavioral/ speech disorders, good academic performance (scores higher than 17), right-handiness, and monolingual. The exclusion criteria were unwillingness to cooperate in the assessments, not having any of the inclusion conditions.

The practical work steps were as follows: Taking a history using a questionnaire, otoscopic examination to confirm the health of the eardrum, immittance audiometry (clarinet middle-ear analyzer) to check the health of the middle ear, the criterion for its normality was the presence of a normal tympanogram with a contralateral auditory reflex (5). Pure tone audiometry to confirm normal hearing (AC33 audiometer, Interacoustics, Denmark), the GAP-N to examine the ability to distinguish time in the auditory system, which is sensitive to the presence of a lesion in the central auditory system and the temporal cortex (2,6). The stimulus used in the GAP-N was white noise that was presented intermittently to the children's ears, and they had to be able to detect intervals of silence or pauses. The duration of the silence intervals was 2, 3, 4, 5, 6, 8, 10, 12, 15, and 20 milliseconds (7). The Kolmogorov-Smirnov test was used to analyze the data to check the normality of the distribution of variables, and the comparison of the means and standard deviations of the groups was performed using the Mann-Whitney test.

RESULTS

Based on the results obtained, the mean and standard deviation of the GAP-N threshold for dyslexic children was 8.6 ± 0.8 (ms) and for normal children it was 5.1 ± 0.06 (ms). The percentage of GAP-N for dyslexic children was

50.4 ± 0.3 (%) and for normal children it was 64.7 ± 0.5 (%). A significant difference was observed between the mean of the distance detection threshold in noise for dyslexic children and normal children (Pv = 0.001). There was a significant difference between the mean of the percentage of GAP-N for dyslexic children compared to normal children (Pv=0.001) (Table 1).

Table 1- Mean (standard deviation) of the distance detection threshold in noise and the percentage of gap-in-noise detection test (GAP-N) according to the study groups: dyslexic (n=25) and normal (n=25)

Variable	Dyslexia Mean (Standard Deviation)	Norm Mean (Standard Deviation)	P value
GAP-N threshold	8.6 (0.8)	5.1 (0.06)	0.001
GAP-N Percentage	50.4 (3.0)	64.7 (0.5)	0.001

DISCUSSION

The findings of this study showed that dyslexic children were weaker in auditory temporal processing ability and had more deficits in the GAP-N than normal children. In this group, the GAP-N threshold (8.6 ms) was higher and the percentage of GAP-N (50.4%) was lower than in the normal group. Whereas, for normal children, the GAP-N threshold was 1.5 ms and the percentage was 64.7%. The findings of our study were consistent with those of Musiek and Moncrieff (2002), who reported a GAP-N threshold of 1.6 ms and a percentage of 60% in their dyslexic children (10). Thus, our study population had lower scores than their study. In examining this difference in scores, it can be noted that our country (Iran) lags behind first-world countries in terms of industrial progress, social development, and livelihood prosperity. Since the gene factor and the environment surrounding the individual are effective in causing dyslexia (1,2). It seems that environmental factors have caused the difference in scores between our study population and theirs. Also, Music et al. (2005) reported a normal GAP-N percentage of 94% in a study of children with central auditory processing disorder (11), while this value was 64.7% for normal children in our study. In other words, auditory temporal processing ability in both the normal and dyslexic groups of our study population was weaker than in these two studies.

It seems that the auditory temporal processing ability is directly related to the advancement of technology and the development of media communications and the level of exposure to auditory stimuli. Carey et al. (2006) stated that the more exposure to auditory experiences, the greater the auditory temporal processing ability, and as a result, the ability to understand and differentiate speech improves (12). If a child has more practice in sound vocalization and speech production, due to the two-way communication that exists in production-perception, she/he is more exposed to her/his own voice, and the development of the central auditory neural regions is faster than if she/he only listens to the conversations of others (13). In other words, Wernicke's area, which is the neural region of speech perception, participates in both speech perception and speech production. Broca's area also participates in speech perception in addition to production (14).

Burkard et al. (2002) reported that auditory temporal processing ability is related to the degree of synchrony of excitation of auditory nerve fibers in both the peripheral and central parts of the auditory system. The degree of this synchronization can be examined by the amplitude of the auditory brainstem response (ABR) waves. In other words, the magnitude of the ABR waves depends on the degree of synchronization of the auditory nerve fibers. If a smaller number of nerve fibers are more coordinated, the amplitudes of the waves are much larger than when a larger number of fibers are stimulated in asynchronously (15).

Also, since information about the intensity and frequency of sound is established by one ear and is received in the cochlea, while understanding the temporal characteristics of sound is possible with the participation of both ears and is received by the superior olivary complex of the brainstem. Therefore, the ability to process auditory temporal information is essential for binaural hearing and, if impaired, can lead to impaired speech understanding in noise, the ability to localization od sounds and specific language disorders (16). Tallal et al. (2005) reported that most children with language impairment, whose auditory temporal processing is weaker than that of normal children, are unable to detect short-term auditory stimuli or speech-blocking silent letters (consonants d, b, p, t) (17).

Consonants are non-periodic speech sounds that have a wide frequency range, low intensity, very short production time, and background noise causes the greatest attenuation for them (18). When the signal (speaker's voice) to noise ratio decreases and the ability to hear speech becomes difficult, brain areas associated with speech processing become more active. This potential capability is evident in listening strategies, because in noisy environments, selective attention to target sounds increases comprehension (19).

Due to auditory temporal processing deficits, dyslexics also have abnormal results in word recognition scores in noise test (22, 21, 20), a method of assessing auditory temporal processing ability in which the noise spectrum stimulates all neural fibers, even those not stimulated by speech. Therefore, spatial information about the location of positive and negative peaks in the speech spectrum is reduced, and speech perception becomes much more difficult than listening in silence (23). Kujala and Brattico (2009) reported that there are differences in the brain structure of dyslexics compared to normal individuals (24). In other words, there are fewer large neurons and more small neurons in the medial geniculate nucleus and thalamus of dyslexics (25), and areas of their cerebral cortex are abnormal, with four cortical layers instead of six (26). Other researchers have also found that the auditory abnormalities in this group of patients cause impairments and defects in the auditory processing of fast sounds (27). If the abnormality is in the frontal cortex, it is associated with some degree of abnormality in the neurons of the thalamus, causing disruption in the temporal processing of sounds. If the abnormality is in the frontal lobe, it will cause problems in the processing of phonemes (28, 27). The study by Musiek et al. (2005) confirmed structural differences in the cortical and subcortical areas of individuals with dyslexia (29). Other researchers found that children with language impairment were unable to distinguish syllables if the consonant of the word was longer than usual. This finding is a strong and convincing evidence that auditory deficits are the cause of speech-language problems and impairments in children (31, 30). By using auditory brainstem responses to complex sounds with speech stimuli, information about speech can be obtained and various types of language and perceptual disorders can be investigated (18).

Halliday et al. (32) also described that deficits in the temporal processing of the auditory system cause disorders in the perception and differentiation of speech sounds, and their consequences manifest in the form of poor phonological skills, dyslexia, and language impairment (32).

In general, speech perception is processed with the participation of cortical and subcortical auditory neural centers. The brainstem is sensitive to the rhythm of speech, and the auditory cortex is sensitive to its meanings and concepts. The brainstem is sensitive to the fundamental frequency of speech (F0), or the lowest frequency of the human voice (the F0 is

400 Hz in children, 200 Hz in women, and 100 Hz in men). However, F0 does not provide the acoustic information necessary for semantic processing of speech, and the auditory cortex is not stimulated by it. Consequently, a sentence spoken in a different dialect by different speakers will have the same meaning for listeners of the same language (19). Without the skills and knowledge to break down words into their phonological components, the ability to transform auditory images and speech sounds into their written symbols is impaired, which impairs reading and writing skills. The brains of dyslexics are unable to process rapid, short, and consecutive speech stimuli, such as explosive consonants or syllables that begin with vowels, in a normal manner (31).

CONCLUSIONS

Dyslexics are weaker in auditory temporal processing than normal children. Since auditory temporal processing and separation of sound patterns play an important role in speech perception, dyslexia is expected to cause deficits in the mechanism of perception/production and reading/writing skills.

Acknowledgments: The author would like to thank all those who collaborated in conducting the study.

Conflict of benefits: This article has one author and has no conflicts of interest.

Funds: This study is an independent research that is not funded or supported by any organization or institution

Abbreviation: Gap-in-Noise Detection Test (GAP-N)

REFERENCES

1. Giraud A-L, Ramus F. Neurogenetics and auditory processing in developmental dyslexia. Current opinion in neurobiology. 2013;23(1):37-42.
2. Hämäläinen JA, Salminen HK, Leppänen PH. Basic auditory processing deficits in dyslexia: systematic review of the behavioral and event-related potential/field evidence. Journal of learning disabilities. 2013;46(5):413-27.
3. Ramus F. Developmental dyslexia: specific phonological deficit or general sensorimotor dysfunction? Current opinion in neurobiology. 2003;13(2):212-8.
4. Cohen.Mimran R, Sapir S. Auditory temporal processing deficits in children with reading disabilities. Dyslexia. 2007;13(3):175-92.
5. Murphy C, Schochat E. How auditory temporal processing deficits relate to dyslexia. Brazilian journal of medical and biological research. 2009;42:647-54.
6. Amaral MIR, Colella-Santos MF. Temporal resolution: performance of school-aged children in the GIN-Gaps-in-noise test. Brazilian journal of Otorhinolaryngology. 2010;76(6):745-52.
7. White-Schwoch T, Woodruff Carr K, Thompson EC, Anderson S ,Nicol T, Bradlow AR, et al. Auditory processing in noise: A preschool biomarker for literacy. PLoS biology. 2015.
8. Iliadou V, Kaprinis S, Kandylis D, Kaprinis GS. Hemispheric laterality assessment with dichotic digits testing in dyslexia and auditory processing disorder. International journal of audiology. 2010;49(3):247-52.
9. Jirsa RE. The clinical utility of the P3 AERP in children with auditory processing disorders. Journal of Speech, Language, and Hearing Research. 1992;35(4):903-12.
10. Moncrieff DW, Musiek FE. Interaural asymmetries revealed by dichotic listening tests in normal and dyslexic children. J Am Acad Audiol. 2002 Sep;13(8):428-37.
11. Musiek FE, Shinn JB, Jirsa R, Bamiou D-E, Baran JA, Zaida E. GIN (Gaps-In-Noise) test performance in subjects with confirmed central auditory nervous system involvement. Ear and hearing. 2005;26(6):608-18.

12. Carey J, Amin N. Evolutionary changes in the cochlea and labyrinth: Solving the problem of sound transmission to the balance organs of the inner ear. Anat Rec A Discov Mol Cell Evol Biol-j. 2006;288(4): 482-9.
13. Wang X. The harmonic organization of auditory cortex. In: Lopez-Poveda EA, Meddis R, Palmer AR, editors. The neurophysiological bases of auditory perception. New York: Springer Science+Business Media, LLC, 2010:211-22.
14. Abrams D A, Kraus N. Auditory pathway representations of speech sounds in humans. In:Katz Jed. In: Katz J, ed. Issues in Hand Book of Clinical Audiology. Six ed. USA: Lippincott Williams & Wilkins. 2002. 501-90.
15. Burkard R, Secor S. Overview of auditory evoked potentials. In: Katz J, Ed. In: Katz J, ed. Issues in Hand Book of Clinical Audiology. Six ed. USA: Lippincott Williams & Wilkins .2002;(3): 233-49.
16. Douglas E.H. Hartley and Andrew f. King.Development of the auditory pathway. Rees A.The oxford handbook of auditory science the auditory brain. First ed. USA. Oxford University Press. 2010:361-387.
17. Tallal P, Fitch RH. Central Auditory Processing and Language Learning Impairments: Implications for Neuroplasticity Research .2005:355-385.
18. Kraus N, Nicol T. Brainstem origins for cortical what and where pathways in the auditory system. Trends Neurosc-j. 2005;28:176 –181.
19. Abrams D A, Kraus N. Auditory pathway representations of speech sounds in humans. In:Katz Jed. In: Katz J, ed. Issues in Hand Book of Clinical Audiology. Six ed. USA: Lippincott Williams & Wilkins. 2002. 501-90.
20. Skoe E٫ KrausN. Auditory Brain Stem Response to Complex Sounds: A Tutorial. Ear & Hearing-j. Lippincott Williams &Wilkins. USA. 2010;31(3);1-23.
21. Ghitza O, Greenberg S. Intelligibility of time-compressed speech with periodic and aperiodic insertions of silence: Evidence for endogenous brain rhythms in speech perception? In: Palmer AP, Lopez-Poveda EA. The Neurophysiological Bases of Auditory Perception. UK. 2010;35:393- 405.
22. Ikeda Y et al. Cerebral activation associated with speech sound discrimination during the diotic listening. NeuroImage-j. 2008:٤٠ (٢), 902-11.
23. Mukari SZM, Mamat WHW. Medial olivocochlear functioning and speech perception in noise in older adults. Audiol Neurotol-j. 2008;13:328-334.
24. Kujala T, Brattico E. Detrimental noise effects on brain's speech functions. Biological Psychology-j. 2009; 81(3):135-143.
25. Yilmaz ST, Sennarog˘lu SG, Sennarog˘lu L, Ko¨se SK. Effect of age on speech recognition in noise and on contra lateral transient evoked Otoacoustic emission suppression. Laryngology & Otology-j. 2007;121: 1029–1034.
26. Walker MM, Shinn JB, Cranford JL, Givens GD, Holbert D. Auditory temporal processing performance of young adults with reading disorders. Journal of Speech, Language, and Hearing Research. 2002;45(3):598-605.
27. Galaburda AM, Menard MT, Rosen GD. Evidence for aberrant auditory anatomy in developmental dyslexia. Proceedings of the National Academy of Sciences. 1994; 91(17): 8010–8013.
28. Deborah W M, Musiek FE. Interaural asymmetries revealed by dichotic listening tests in normal and dyslexic children. Journal of the American Academy of Audiology. 2002;13(8):428-37.
29. Musiek FE, Bellis TJ, Chermak GD. Nonmodularity of the central auditory

nervous system: implications for (central) auditory processing disorder. American Journal of Audiology. 2005;14(2):128-38.

30. DW, Black JR. Dichotic listening deficits in children with dyslexia. 2008;14(1):54-75.

31. Kumar P, Singh NK, Ghosh VPG. Behavioral assessment of children at risk of central auditory processing disorder without reading deficits. J Hear Sci 2013;3(4):49–55.

32. Halliday LF, Bishop DV. Auditory frequency discrimination in children with dyslexia. Journal of Research in Reading. 2006;29(2):213-28

***Corresponding Author**

Dr. Seyede Farank Emami

Associate Professor, Hearing Disorder Research Center, Department of Audiology, Faculty of Rehabilitation, Hamadan University of Medical Sciences. Hamedan, Iran.

Mobile: 989188118476,

Email: faranak_imami@yahoo.com

ORCID code: 0000-0002-8034-4334

How to cite this article

Emami S.F.: Investigation Of Auditory Temporal Processing Ability in Dyslexic Children -- UPJOHNS; June 25; 13(2); page: 25-32