

THE EFFECTS OF MUSICAL STIMULATION ON CHILDREN WITH DYSLEXIA

UČINKI GLASBENE STIMULACIJE NA OTROKE Z DISLEKSIMO

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Abstract: Dyslexia affects 5-12% of school-aged children, posing challenges in reading, spelling, and language processing. This paper explores the benefits of musical stimulation in enhancing cognitive functions and reading skills in dyslexic students. Previous research highlights that musical interventions improve phonological awareness, reading accuracy, and cognitive processing through shared neural mechanisms between music and reading. Integrating musical activities into educational practices can create an inclusive environment, supporting individualized learning aligned with Gardner's Theory of Multiple Intelligences. This approach promotes academic and personal growth and diversity, offering effective strategies for overcoming challenges faced by students with learning disabilities, promoting inclusivity in the classroom.

Keywords: dyslexia, inclusive education, musical stimulation, reading skills, rhythm

Izvleček: Disleksija prizadene 5–12% otrok šolske starosti in povzroča težave pri branju, črkovanju ter jezikovnem procesiranju. Pričujoči članek raziskuje koristi glasbene stimulacije oz. njen vpliv na izboljšanje kognitivnih funkcij in bralnih spretnosti pri učencih z disleksijo. Prejšnje raziskave poudarjajo, da glasbene intervencije izboljšujejo fonološko zavedanje, natančnost branja in kognitivno procesiranje preko skupnih nevrlnih mehanizmov med glasbo in branjem. Integracija glasbenih dejavnosti v izobraževalne prakse lahko ustvari vključujoče okolje, ki podpira individualizirano učenje v skladu z Gardnerjevo teorijo o mnogoterih inteligentnostih. Tak pristop spodbuja akademski in osebni razvoj ter raznolikost, hkrati pa ponuja učinkovite strategije za premagovanje izzivov učencev z učnimi težavami in podpira inkluzivnost v učilnici.

Ključne besede: disleksija, inkluzivno izobraževanje, glasbena stimulacija, bralne spretnosti, ritem

INTRODUCTION

Dyslexia remains the most prevalent learning disability among school-aged children and it continues to draw attention to many researchers around the world. According to the *Dyslexia Compass: National Dyslexia Measurements Across Europe Report* (2022, p. 12), an estimated 5–12% of schoolchildren are diagnosed with this learning disability, characterized

by difficulties in reading, spelling, and language processing. These challenges extend beyond academic performance, often affecting students' self-esteem, motivation, and overall cognitive development. Traditional teaching methods may not adequately address the unique needs of students with dyslexia, which emphasizes the need for innovative strategies that could support their learning and overall experiences in school. Educators can benefit from specialized training, to be able to recognize different forms of dyslexia and apply effective strategies for managing it. Careful assessment of the students could help identify specific gaps in their skills and create individualized programmes (Martan et al., 2024). This approach contributes to the creation of a supportive and engaging classroom environment, allowing students to progress and develop according to their individual abilities.

In managing learning disabilities associated with dyslexia, this paper examines research findings on the positive effects of musical stimulation in helping schoolchildren. Numerous studies (Bouloukou et al., 2021; Chobert et al., 2012; Flaunacco et al., 2015; Habib et al., 2016; Overy et al., 2001; Zuk et al., 2018) have shown that musical activities have a positive effect on children diagnosed with dyslexia, particularly in language and cognitive development. Through this review, we will explore the shared neural processes between music and reading and how understanding this connection underscores the importance and benefit of integrating musical activities in educational systems to manage dyslexia in children.

INDIVIDUALIZATION AND DIFFERENTIATION

Researchers in the fields of pedagogy and linguistics (Lindner & Schwab, 2020) believe that students differ in their cognitive abilities, learning pace and intensity, interests, attitudes, reactions, motivation, and various learning experiences. Many educators emphasize the importance of appropriate individualization in teaching by adapting pedagogical methods to students' abilities, and of differentiation to ensure important educational outcomes (Đorđević, 2009).

Individualization and differentiation represent primary goals in pedagogical work. Psychologist Piéron (1973, p. 158) defines individualization as a 'pedagogical procedure that, in contrast to frontal teaching, allows each student in the class to perform the individualized tasks, as determined by the teacher, which correspond to the student's actual abilities'. The core of an effective educational process is the alignment of teacher skills with the individual needs and abilities of students (Firth et al., 2013). The main challenge in contemporary education is for teachers to identify the potential of the students and adjust the educational outcomes and programmes to accommodate the strengths of different groups of students, including those with dyslexia (Martan et al., 2024, p. 537). According to Berliner (2004, p. 329), educators cannot only rely

on strict formulas, guidelines, or rules. He states that the teaching process often requires educators to be flexible, provide individualized programmes for students, be creative, improvise, and have emotional sensitivity.

To help each student achieve their individual abilities and learning skills (Gardner, 1999), it is important to apply different types of intelligence. This type of approach fosters individualization in education and helps maximize each student's potential by focusing on their unique needs and interests. This type of teaching adapts educational programmes and content to every student based on Gardner's (1999) concept of 'education for personal development'. His Theory of Multiple Intelligences (1983) plays a key role in this approach, as he identifies eight types of intelligence: linguistic, logical-mathematical, spatial, musical, bodily-kinaesthetic, naturalistic, interpersonal, and intrapersonal intelligence (Gardner, 1999). He argues that these intelligences often work together and complement one another. The theory also suggests that each person excels at specific tasks in certain areas. From an educational perspective, Gardner's theory leads to the creation of different teaching methods with the goal to help students learn content effectively and develop their individual abilities, considering factors such as learning styles, social, cultural, and linguistic background, physical characteristics, and resilience.

DYSLLEXIA – TERMINOLOGICAL DEFINITION

According to the International Dyslexia Association (IDA), dyslexia is a neurological learning disability that causes challenges with word recognition, spelling, and decoding, due to phonological deficits. Despite strong cognitive abilities and instruction, these difficulties still occur. As a result, secondary effects include reduced reading comprehension and limited vocabulary development. The American Psychiatric Association (n.d.) defines dyslexia as a type of specific learning disorder (SLD), with significant challenges in reading skills (accuracy, fluency, comprehension). Reading difficulty can emerge even before formal reading instruction, with children having problems in syllable recognition or rhyming. Dyslexic individuals struggle to connect letters with sounds, resulting in slow reading and problems with writing and spelling.

Psychologists Stein and Walsh (1997, p. 148) note that dyslexia was first mentioned in 1887 in the work of German neurologist Kussmaul, who described it as so-called 'word blindness' in individuals with normal intelligence, but who distort certain words while pronouncing. Neuropsychiatrist Golubović (2011) defines dyslexia as a specific difficulty in the development and acquisition of reading skills, present in individuals with normal intelligence, good vision and hearing, appropriate motivation, and other psychological, educational, and social conditions. She also emphasizes that dyslexia represents a significant discrepancy between the students' actual ability and the expected level of

reading ability for their age and intellectual development. Dyslexia also involves deficits in visual processing, phonological coding, and language comprehension, as well as difficulties in perception and fast processing of information. The British Dyslexia Association (n.d., p. 4) defines it as a difficulty that impacts reading, spelling accuracy and fluency, often linked to challenges in phonological awareness, verbal memory, and processing speed. It affects individuals across the intellectual spectrum and exists on a continuum without clear boundaries. Dyslexia can also involve co-occurring difficulties in areas such as motor coordination, language, concentration, and organization, although these alone are not indicators for the condition. The severity of dyslexia is best assessed by examining the individual's response to targeted intervention, with some individuals also experiencing visual and auditory processing challenges (British Dyslexia Association, n.d., p. 4).

THE CAUSES OF DYSLEXIA

Despite extensive research on the origins and causes of dyslexia, scientists continue to debate its potential causes. Some explanations focus on biological factors, while others support cognitive, genetic-neurobiological, and behavioural approaches. According to Golubović (2011), the causes of dyslexia can have three perspectives: cognitive, genetic-neurobiological, and behavioural. However, depending on the researcher, there are different perspectives on the cause of this condition. Golubović (2011) identifies three groups of theories regarding the cause of dyslexia. The first group includes visual-spatial deficits, which make it difficult to learn, analyse, and remember visual material (words and numbers). These deficits hinder the simultaneous audiovisual analysis required for reading and writing. The second group of theories involves limited auditory memory, where students with reading difficulties struggle with tasks that require phonological processing. The third group defines reading difficulties as the result of general or specific language deficits, such as a limited vocabulary or difficulty grouping sounds into words and then into sentences. These theories suggest that reading and writing difficulties are affected by organic, psychological, and social factors, as well as by slower cognitive development in students.

Lyon et al. (2003) argue that, while these students can achieve success in reading and writing and attain high academic performance, they often expend significantly more effort than their peers to complete tasks both inside and outside of the school context. The authors also emphasize that difficulties in reading or writing may negatively impact students' motivation and have broader consequences for their cognitive, emotional, and social development.

Recent studies have increasingly highlighted the connection between music and cognitive development, particularly in children with dyslexia. Studies exploring the relationship between music and reading skills (Besson et al., 2011; Cogo-Moreira et al., 2012; Corrigan & Trainer, 2011; Flaugnacco et al., 2015; Herholz & Zatorre, 2012; Münte et al., 2002) have shown that the brain of a musician is an excellent example of neuroplasticity. Research demonstrates that music engages various cognitive processes, including attention, memory, auditory perception, and motor coordination, which are domains frequently impaired in children with dyslexia. Musical stimulation has shown a positive correlation with improvements in speech perception, reading, and overall cognitive development.

Table 1
Eligibility criteria

Item	Inclusion criteria	Exclusion criteria
Participants	Dyslexic individuals	Only healthy individuals (non-dyslexic)
	Individuals with low-reading level	Sample without group of dyslexic individuals
	Children, adolescents, and young adults	Individuals under 6 years
	Studies with single-group design (only dyslexic individuals)	
	Studies with comparison group (both dyslexic and non-dyslexic individuals)	Adults and older adults
Concept	Studies including music stimulations/interventions (rhythm, singing, movement)	Exclude music stimulations/interventions
	Studies focusing on reading difficulties/literacy development	Music interventions unrelated to reading difficulties/literacy development
	No interventions/observational study	
	Correlation of dyslexia and music	
Context	Studies published in the English language	Studies published in non-English languages
Evidence sources	Qualitative, quantitative, mixed method approaches, case studies, systematic reviews.	Studies published before 2015
	Studies published from 2015-2024	

The objectives of this paper focus on exploring which musical stimulations are the most effective in improving reading skills in dyslexic students and whether they can be integrated into the educational context. In the process of study selection we followed the designed inclusion criteria (Table 1). The following section provides a review of previous studies ($n=10$) regarding the effects of musical stimulation on enhancing literacy and language skills for dyslexic children. The summary of study characteristics, including study design, participants, data collection, intervention type, method, and key findings are presented in Table 2.

RHYTHM-BASED TRAINING

A study by Couvignou et al. (2023) examined the longitudinal relationships between musical abilities, phonological skills, and literacy development in children, including those with and without a family risk for dyslexia. The study focused on whether early musical impairments influence reading difficulties and examined the role of family risk (FR) for developing dyslexia disorder. The study assessed 130 French-speaking children, including 31 with a family risk for dyslexia. Assessments took place at three time-points: kindergarten, first grade, and second grade. Using the LAMDA test, study evaluated respondents' music perception (pitch/time change perception), phonology (phonological awareness, verbal memory), and literacy (reading, spelling). Findings revealed that early musical skills had a minimal indirect effect on later literacy, mediated by phonology, indicating that while music abilities relate to phonological skills, they are not significant predictors of reading outcomes. The FR group showed impairments in musical and phonological skills, but these deficits did not directly cause reading difficulties, suggesting an association rather than causation. Family risk and phonological abilities were stronger predictors of reading outcomes. The study concluded that while musical impairments may coexist with dyslexia risk, they are insufficient for predicting or screening dyslexia.

One study by Ahokas et al. (2024) explored the effectiveness of enhanced rhythm training in improving reading skills and working memory performance in primary school children (6-8 years). The study examined the connection between rhythm perception and literacy skills, particularly among children with lower initial reading levels, as they often struggle with reading and phonological processing. Embodied rhythm training, integrating movement and rhythm exercises, was examined to see if it can positively impact cognitive functions that are essential to reading skills. The sample consisted of 70 children in total aged between 6 and 8 years from a Finnish school. However, 56 participants completed the pre- and post-intervention data in the working memory and 52 participants completed literacy skill evaluations at all four measurement points (pre, post, and two follow-ups). Participants were divided

Table 2

Summary of study characteristics

Study	Study design	Data collection	Intervention/ Stimulation	Method/ approach	Key findings	Participants' characteristics
Rhythm-based training (n=4)						
Couvignou et al. (2023)	Quantitative study	LAMDA test Three time points: kindergarten, first grade, and second grade	Observational longitudinal study Activities: pitch/time change perception, memory, reading, and spelling	Rhythm-based training and auditory processing	Phonological skills mediated the relationship between musical abilities and literacy. Family risk for dyslexia and phonological abilities were stronger predictors of reading outcomes.	French-speaking children (n=130) including family risk for dyslexia (n=31)
Ahokas et al. (2024)	Quantitative study	ALLU reading test. Corsi Blocks test Pre, post, and follow-ups at 8 and 20 months	Experimental group received rhythm-based training: percussion, body percussion, movement, beat synchronization. Comparison group received general music lessons.	Rhythm-based training (Orff)	Improvement in reading and memory for lower-level readers, rhythm training feasible for schools.	56 children (6-8 years) Experimental (n=29) Control (n=27) Subgroup: lower-level readers (n=15 in experimental, n=12 in comparison group)
Zuk et al. (2018)	Quantitative study	fMRI exercises and standardized reading assessments (TOWRE, TOSWRF) KBIT for nonverbal cognitive abilities	Rhythm and sound processing Activities: phonological and control exercises, accuracy/reaction time measures	Rhythm-based training and auditory processing	Musically trained children showed increased brain activity in reading/phonological areas compared to untrained groups. Dyslexic children had lower reading accuracy.	40 healthy children (6-13 years) Musically trained (n=16) Musically untrained (n=13) Musically untrained with dyslexia (n=11)

Study	Study design	Data collection	Intervention/ Stimulation	Method/ approach	Key findings	Participants' chara- cteristics
Flaunacco et al. (2015)	Quantitative study	Cognitive ability assessments and phonological tasks Pre and post intervention assessments	1. Experimental group: rhythm training (percussion, rhythm syllables, body movement with music) Training sessions 1 hour, 2 a week (30 weeks in total) 2. Control group: painting lessons (creativity and fine motor skills)	Rhythm-based training (Kodaly and Orff)	Both groups improved in general reading skills, but the music group showed greater gains in reading accuracy and phonological awareness.	Dyslexic Italian-speaking children (n=48) 8-11 years Experimental group (n=24) Control group (n=24)
Systematic review – rhythm and melody-based training (n=2)						
Cancer and Antonietti (2022)	Systematic review	18 studies reviewed including intervention types: auditory processing training, music training, combined interventions	1. Auditory (phoneme processing, non-speech rhythm) 2. Music (rhythm, singing, clapping, percussion) 3. Combined music/auditory and reading	Rhythm and melody-based training and auditory processing	Combined interventions improved reading and phonological skills more than single interventions.	Children and adolescents with reading difficulties
Di Paolo and Todino (2023)	Systematic review (PRISMA-ScR)	Review of 31 studies focused on music-based and digital technology-integrated interventions for dyslexic students	1. Music exercises (tapping, rhythm patterns, intonation, pitch variation) 2. Technological tools (voiceover, sound-symbol recognition)	Rhythm and melody-based training with digital technologies	Combined interventions improved reading and writing skills; highlighted the need for a holistic approach.	Elementary school students with diagnosed dyslexia
Rhythm and melody-based training (n=4)						
Habib et al. (2016)	Mixed-methods approach	Study 1 (short-term): Intensive 3-day CMT with pre and post tests on auditory and phonological skills	Study 1 (short term): Daily 45 minute sessions with rhythm training (tapping exercises), piano instructions and movements activities	Rhythm-based training (CMT)	Study 1 Dyslexic children improved in syllable duration discrimination and phoneme categorization post-training. Pitch categorization showed no significant improvement.	34 participants Experimental group - dyslexic children (n=12) Control group - non-dyslexic children (n=22)

Study	Study design	Data collection	Intervention/ Stimulation	Method/ approach	Key findings	Participants' characteristics
Bouloukou et al. (2021)	Quantitative study	Study 2 (long-term): CMT during 6 weeks of workshops with assessments before, during, and after	Study 2 (long term): Weekly workshops (3hrs/week) including group musical activities (singing, percussion) and phonological tasks	Rhythm and melody-based training (CMT)	Study 2 Long term CMT led to sustained gains in phonological awareness and reading accuracy, with minimal effects on visual-spatial skills.	32 dyslexic Greek-speaking students (8-9 years) Experimental group (n=16) Control group (n=16)
Bouloukou (2022)	Quantitative study	LAMDA test (rhythm, word recognition, visual sequences, and grammar) Pre and post intervention test	12 week rhythm-based music training programme (40 minutes each session) Rhythm walking while bouncing a ball, metronome sound identification, and playing percussion instrument using musical value cards	Rhythm based (Orff and Dalcroze) training	Experimental group showed improvements in rhythm reproduction, visual sequences, word recognition, and pattern completion.	64 Greek-speaking children (7-11 years) Dyslexic group (n=32) Experimental (n=16) Control (n=16) Non-dyslexic group (n=32)
Christiner et al. (2022)	Mixed-method approach	Neuropsychological measurements (MEG), musical aptitude test (AMMA)	12-session music intervention (20 minutes each), rhythm training Measured skills: image/word recognition, spelling, text comprehension, memory, and perception of music characteristics (rhythm, harmony, melody)	Rhythm-based training and auditory processing (Orff)	Significant improvements in word recognition, grammar, spelling, visual sequences, and rhythm reproduction in the experimental (dyslexic) group. Positive effects on auditory-visual memory, attention, concentration, and verbal abilities.	Adolescents and young adults German-speakers (n=52) Non-dyslexic (n=26) Dyslexic (n=26)

into two: an experimental group ($n=29$) receiving rhythm-based music training and a comparison group ($n=27$) receiving general music lessons. The intervention consisted of 13 music sessions (once a week) over the period of three months, integrated into regular school schedules. The experimental group intervention activities included percussive instruments (e.g. djembe), body percussion, movements synchronized with beats, and simple rhythm patterns practiced through clapping or drumming. These interventions, influenced by Karl Orff's method, were designed to develop beat synchronization, and enhance spatial awareness and motor skills, as well as to improve phonological awareness. The comparison group followed general music education activities, including singing and melody-focused exercises, without specific rhythm or movement activities. Among the children in both groups (15 out of 29 children in the experimental and 12 out of 27 in the comparison group), those identified as lower-level readers were a subgroup with lower literacy skills. The literacy assessment was conducted using the Finnish ALLU test (Ala-asteen Lukutesti, ie. Reading Test for Primary School) (Lindeman, 2005), and working memory through the Corsi Blocks test (Vandierendonck et al., 2004) before and after the intervention, with additional follow-ups at 8 and 20 months. Results showed no significant differences in overall reading development between groups, but lower-starting-level readers in the experimental group demonstrated significant and sustained improvements in literacy skills (after 17 months) compared to the comparison group, underscoring the long-term benefits of rhythm training. Regarding the study's hypothesis that rhythm training benefits cognitive functions linked to reading, the experimental group showed moderate improvements in visuospatial working memory, which supports this hypothesis. The study highlights the feasibility of embedding rhythm-based interventions into school curricula, without requiring specialized resources, and their potential to support children with early reading difficulties. Findings suggest that rhythm-focused music training can serve as an effective intervention for at-risk readers in educational settings.

Zuk et al. (2018) aimed to examine neural correlates of phonological processing in 40 healthy English-speaking children, aged from 6 to 13 years. Children were divided into three groups including: (1) musically trained children ($n=16$); (2) musically untrained children ($n=13$); and (3) musically untrained children with diagnosed dyslexia or scoring below 90 on standardized reading assessments ($n=11$). The primary goal was to explore if musical training enhances phonological processing and whether these improvements can benefit children with dyslexia. The study used functional magnetic resonance imaging (fMRI) to measure brain activity during a phonological task where children had to identify whether two spoken words started with the same initial sound. They compared all three groups. A control task was also performed, which involved identifying if two words were spoken in the same voice (gender matching). During the procedure, accuracy and reaction time were

recorded to assess their performance. Reading skills were evaluated using the Test of Word Reading Efficiency (TOWRE) and Test of Silent Word Reading Fluency (TOSWRF). Nonverbal cognitive abilities were measured using the Kaufman Brief Intelligence Test (KBIT). The findings showed that musically trained children demonstrated increased brain activity in areas related to reading and phonological processing compared to musically untrained children with and without dyslexia. Children with dyslexia showed lower reading accuracy, indicating challenges in phonological processing. These results suggest that musical training may promote neuroplasticity in brain regions linked to reading, potentially supporting compensatory mechanisms in children with dyslexia. Similar interventions could be used in schools, involving phonological tasks (rhythm and sound processing) to improve auditory discrimination, and singing activities to reinforce sound-letter associations and enhance distinguishing similar-sounding words. These activities could be integrated into the curriculum, providing an engaging and creative way to support students with dyslexia.

A study by Flaugnacco et al. (2015) explored whether musical training could improve phonological and reading skills in children with dyslexia. Similar to Chobert et al. (2012), it involved two groups of dyslexic children: one receiving musical training based on Kodaly and Orff methods focused on rhythm and temporal processing, and a control group receiving painting lessons. The music group participated in weekly workshops over a period of 7 months, engaging in rhythm-focused activities, using percussion, rhythm syllables (ti, ta, etc.) and body movement with music as accompaniment. In contrast, the painting group focused on visual-spatial and fine motor skills, including creativity. Both groups also practiced daily reading exercises at home. Before and after the intervention, assessments measured reading speed, phonological awareness, and memory. While both groups showed improvement in general reading skills, the music group demonstrated gains in reading accuracy and phonological skills, with rhythm reproduction identified as the strongest predictor of phonological awareness. The results highlight rhythm's unique role in supporting language processing in dyslexic children by enhancing essential temporal and phonological processing skills, which are crucial for reading.

The study by Bouloukou et al. (2021) focused on measuring improvements in skills related to rhythm perception, memory, attention, and language processing. The study involved an experimental group (receiving customized rhythm-based music training) and control group (following the conventional curriculum). All participants from both groups had previously taken standard music education but had no private music lessons. This programme was tailored to dyslexic students' needs, emphasizing multisensory engagement, including kinaesthetic, vocal-acoustic, visual-spatial, and rhythm perception skills, based on Dalcroze and Orff methods. Researchers applied LAMDA (Protopapas & Skaloumbakas, 2008) testing both before and after the musical training

to assess rhythm, word recognition, visual sequences, and grammar. The experimental group showed significant improvements in rhythm and recognizing words, while the control group had minimal changes. The results suggest the interventional musical training had a positive effect on the stimulus-recognition abilities of students with dyslexia when compared to the traditional music classes. They emphasized that activities involving kinaesthetic, multisensory and spatial elements were particularly effective for students with dyslexia, but that further research needs to confirm the long-term effects of this approach.

Bouloukou (2022), building on this foundation, expanded the scope by assessing broader academic learning skills such as grammar, spelling, visual sequences, and auditory-visual memory. The study aimed to improve musical perception and rhythmic education in elementary school students with dyslexia through specialized teaching methods addressing their language difficulties. The study involved 32 dyslexic children (divided into experimental and control groups) and 32 non-dyslexic children. The experimental dyslexic group participated in a 12-session music intervention (20 minutes per session) while the control group followed the standard curriculum. The effectiveness of the intervention was assessed using the LAMDA test (Protopapas & Skaloumbakas, 2008) which evaluated skills such as image and word recognition, spelling, text comprehension, vocabulary, working memory, non-verbal mental ability, and perception of music characteristics (rhythm, harmony, melody). The results showed significant improvements in word recognition, grammar, spelling, visual sequences, and rhythm reproduction in the experimental dyslexic group. The study highlights the value of tailored rhythmic activities in improving auditory-visual memory, attention, concentration, and verbal abilities, positively affecting overall academic performance. Both studies emphasize the positive effect of rhythm-based music training on dyslexic students, with the study from 2022 including broader language and cognitive skills, underscoring the need for an inclusive music curriculum to support the cognitive development of dyslexic children.

COMBINED RHYTHM AND MELODY-TRAINING

The literature review by Cancer and Antonietti (2022) examined the specific effects of music-based and auditory-based interventions on reading difficulties in children and adolescents. They selected studies ($n=18$) published in the last fifty years and categorized them into four distinct groups according to the main component of the interventions they employed: (1) auditory processing training only; (2) auditory and reading training combined; (3) music training only; and (4) music and reading training combined. The study evaluated the outcomes of selected research using standardized tests on reading, phonological awareness, and related skills. The auditory-based interventions (training

perceptual abilities) in the studies included activities such as frequency discrimination, auditory discrimination, phoneme processing, temporal synchronization, non-speech rhythm, etc. The music-based interventions employed rhythm training, singing, chanting, clapping and percussion games, rhythm body movements, marching to the beat, and other musical games, targeting different auditory skills (rhythm perception, reproduction and synchronization). Integrated interventions combined music or rhythm-based training with specific reading exercises. The findings showed that studies focusing only on auditory-based training showed improved auditory discrimination but had limited transfer effects on reading. Studies employing only music-based training demonstrated enhanced phonological awareness, rhythm perception, and auditory processing, but their impact on reading improvement was inconsistent. In contrast, studies that combined interventions (music/auditory and reading tasks) were more effective in improving reading accuracy and phonological skills compared to auditory or music interventions alone. The study concluded that integrated interventions combining music or rhythm-based training with reading exercises provided the most significant improvements in reading and phonological awareness in children and adolescents with reading difficulties. They also found no evidence to support the significance of training duration in affecting the efficacy of these interventions. Findings indicate that combined musical interventions enhance neural encoding of rhythm and phonological processing, which are essential for reading development.

Di Paolo and Todino (2023) also did a systematic literature review, following the PRISMA-ScR method, aiming to explore the potential of combining music and new digital technologies to enhance reading and writing skills in elementary school students with dyslexia. The study selected 31 relevant contributions and examined whether previous studies recognized the efficacy of music-based interventions combined with technology and how they can support dyslexic students in their literacy development. Interventions included in the selected studies were focused on: (1) music and rhythmic exercises (synchronized tapping games, rhythm patterns, intonation, pitch variation) to enhance rhythmic skills; and (2) technological tools (voiceover functions, sound-symbol recognition) to improve sound-letter recognition and writing skills. This review demonstrated that studies employing rhythm exercises and new technology tools significantly improved reading and writing skills in dyslexic students. It also highlighted one of the limitations present in many selected studies, which focus primarily on rhythm, while overlooking other aspects of music. The research suggests that a more holistic approach in integrating music as a whole (as an intervention) would better support diverse cognitive and learning styles of students. The study underscores the importance of enhancing technological skills in primary education and integrating digital resources to support learning, especially for students with learning difficulties and special educational needs. The implications suggest an inclusive educational approach

that combines a variety of musical styles and technological tools to effectively address the individual learning needs of dyslexic students.

Habib et al. (2016) explored the impact and effectiveness of Cognitive Musical Training (CMT) for improving reading abilities in children with dyslexia. The research framework consisted of two studies. The first study measured the short-term effects of intensive cognitive-musical training (CMT) on dyslexic children ($n=12$), over 3 consecutive days (18 hours total). The control group were non-dyslexic children ($n=22$) who did not undergo the CMT programme. The experimental group (dyslexic children) was divided into three groups and all of them participated in three training sessions during the programme. The speech therapists designed the programme in order to improve children's auditory and motor skills, involving various musical components in the programme exercises. All children from the experimental group participated in three training sessions (each lasting 45 minutes), which included: (1) music exercises (tapping in synchronization with heard rhythm sequence, tapping with the written notation of a rhythm); (2) music education with piano instruction; and (3) percussion and movement exercises. Each day included these exercises, but with differences in the level of difficulty. The assessments involved categorical perception (phoneme identification and discrimination), syllabic duration, and pitch discrimination. Their performance level was measured both before and after each training, which was also measured in the control group, who did not receive any interventions. Results showed that post-training, children in the experimental group exhibited improvement in categorical perception of syllables, particularly in duration discrimination. Pitch discrimination did not show significant improvement. Positive effects of CMT were found, suggesting that short-term musical interventions can help in improving cognitive and auditory processing skills linked to language development.

The second study aimed to extend the findings from the first study by evaluating the long-term effects of the CMT programme on dyslexic children ($n=12$), conducted over six weeks. The study focused on determining whether improvements observed in cognitive, auditory, and phonological tasks during short-term CMT were sustainable and applicable in real classroom settings. The children were divided into four groups, depending on their reading proficiency, and they participated in weekly workshops (three hours per week). The programme included both full-class sessions ($n=12$) and small group activities ($n=4$), each lasting approximately 45 minutes. Full-class sessions focused on musical activities (rhythm exercises, singing, and percussion to enhance auditory discrimination and attention). Small group sessions targeted phonological tasks such as sound identification, syllable repetition, and letter-sound matching. The programme's effectiveness was evaluated through a variety of language, reading, and cognitive tests before, during, and after the six-week programme. Results indicated significant improvement in phonological

awareness, syllable categorization, and reading accuracy during the CMT period, particularly for tasks related to phonemic boundaries and discrimination. Findings showed minimal effects on visual-spatial skills, writing, and memory. These improvements were maintained even after the programme ended, suggesting that the training had beneficial, lasting effects on certain cognitive skills linked to reading difficulties.

A recent study by Christiner et al. (2022) primarily explored the music-related factors, focusing on differences in singing, musical aptitude, and tone language ability (Mandarin) between adolescents and young adults with and without dyslexia. Considering the shared characteristics of music and language, the study aimed to identify distinct mechanisms for language processing in both the dyslexic ($n=26$) and control group ($n=26$). In order to assess language ability, the study employed Mandarin tone-discrimination, syllable recognition, and syllable pronunciation tasks. None of the participants were familiar with the Mandarin language and they were all German-speakers. The participants' musical aptitude was evaluated using Gordon's Advanced Measures of Musical Audiation (AMMA test), and their singing ability was examined by professional singers, according to melody accuracy, vocal range, voice quality, and rhythm. Another task for participants was to report their singing behaviour during the childhood and adolescence period. Brain responses (P_1 , N_1 , P_2) to various instrumental and artificial tones were recorded using neurophysiological measurements (MEG) to examine auditory processing, attention, and learning. The study found significant differences between the two groups. Dyslexic participants showed prolonged P_1 , N_1 , and P_2 responses, indicating slower and less efficient auditory processing. They also scored less in Mandarin pronunciation, tone discrimination, singing ability and overall musical ability than the control group, suggesting that dyslexia affects both language and musical sounds processing. Tasks combining sound-symbol correspondence (recognizing tonal changes in Mandarin) and musical ability (singing) were particularly effective in distinguishing dyslexic from non-dyslexic individuals. The study concluded that dyslexia involves auditory sensory integration deficits, and musical training could help improve auditory processing and language abilities in individuals with dyslexia.

CONCLUSION

Musical training has shown a tremendous effect on enhancing cognitive functions, phonological processing, and literacy skills in children with dyslexia. Numerous studies have highlighted the importance of integrating music stimulations into educational practices to provide a creative and effective approach to support children with learning disabilities, offering benefits that extend beyond traditional teaching methods. Comparing these interventions and their

effectiveness reveals which approaches are most beneficial for dyslexic children and which are the most applicable in school settings, including rhythm-based exercises, singing, percussion, body movement, auditory processing tasks, and the use of digital technologies.

Rhythm-based interventions have been conducted in four studies (n=4), aiming to improve reading abilities in dyslexic children. The study by Habib et al. (2016) found that rhythm-based exercises (drumming, clapping, and rhythmic games) significantly improved reading accuracy, syllable categorization, and phonological awareness. Flaunacco et al. (2015), in their longitudinal study, demonstrated that rhythm-based musical interventions (percussion, rhythm syllables, body movement with music) helped dyslexic children improve phonological processing and reading skills. Ahokas et al. (2024) explored the impact of Orff-based rhythm exercises, which emphasized (body) percussion, movement, and beat synchronization, leading to improved phonological awareness, attention, and reading skills. Zuk et al. (2018) demonstrated that implementing tapping and synchronization tasks improved auditory-visual memory, attention, and reading fluency. These studies suggest that rhythm-based stimulations, especially those incorporating movement and repetitive patterns, can effectively support dyslexic children's literacy development. Percussion instruments have been found to be particularly effective in improving auditory-visual memory, attention, and spelling in dyslexic children. Studies by Bouloukou et al. (2021) and Bouloukou (2022) demonstrated that rhythm-based interventions (percussion instruments, bouncing a ball while walking in rhythm, metronome sound identification) significantly enhanced cognitive abilities and improved academic performance. Percussion activities engage students musically involving the use of both brain hemispheres, which helps with processing sounds and improving memory. These interventions are designed according to the specific needs of dyslexic students, providing an individualized approach to learning.

Studies that *combined rhythm and melody stimulations* (n=6) have shown that a holistic approach is the most beneficial in improving literacy and cognitive processes in children with dyslexia. Christiner et al. (2022) explored the differences in singing, musical aptitude, and language processing between dyslexic and non-dyslexic individuals. Findings showed that dyslexic children exhibit auditory sensory integration deficits, but tasks combining musical ability and language, like singing and tone discrimination, can help children overcome auditory sensory integration deficits and improve language processing. Singing and tone discrimination target the auditory processing areas of the brain, enhancing their ability to decode written words. Di Paolo and Todino (2023) highlighted that melodic reading, which pairs words with melody, enhanced word recognition and fluency in reading. These exercises engaged both musical domains, fostering neuroplasticity and language processing. Literature reviews (Cancer & Antonietti, 2022; Di Paolo & Todino, 2023) emphasized

that integrated interventions combining music and rhythmic exercises alongside reading activities yield the most significant improvements in literacy. Di Paolo and Todino (2023) highlighted the use of music-based digital platforms that combine rhythm and reading exercises, which help students with sound-letter recognition and increase their engagement. These digital resources provide personalized learning experiences and immediate feedback, making them a valuable addition to classroom settings.

PRACTICAL APPLICATION

In order to integrate musical activities into classroom settings, it requires careful alignment with the curriculum outcomes and the unique needs of students with dyslexia. Through implementation of these activities, educators can enhance the academic success and wellbeing of each student, while acknowledging their cognitive, emotional, social and creative development. By integrating a combination of rhythm- and melody-based stimulations into the existing curriculum and lesson plans, schools can provide tailored support for children with dyslexia, and an engaging learning environment that contributes to their overall wellbeing. Practical implications include: (1) introducing short and structured music sessions (15-20 minutes daily) that include rhythm exercises and singing activities as a part of a regular primary school schedule; and (2) integrating music-based educational apps for personalized learning, with real-time feedback on rhythm and sound-letter associations. This holistic approach to learning promotes an inclusive educational experience, and enhances motivation and students' engagement, empowering all children to reach their maximum academic performance.

LIMITATIONS

Although this paper emphasizes specific benefits of musical stimulations for children dealing with dyslexia, there are several limitations that need to be addressed. Many of the reviewed studies involve a small sample size which limits the generalization of findings across different populations. The duration of interventions are predominantly focused on short-term effects, questioning the sustainability of the positive effects over extended periods. The primary focus of studies is on rhythm-based stimulations and auditory processing tasks, often overlooking the potential of including other valuable musical dimensions, such as melody, harmony, and improvisation. There is a challenge in drawing consistent interpretations and comparison of results because of the methodological variability, such as different assessment instruments for measuring phonological awareness and literacy skills in participants. Individual differences,

such as the severity of dyslexia among participants and their prior musical training, further limit the applicability of outcomes to a broader context. In order to address these challenges, future studies could focus more on conducting longitudinal research that examines the long-term effects of a broader range of musical stimulation (apart from rhythm) on a larger and diverse sample. Expanding the focus to include underexplored aspects of musical stimulation (harmony, melody, improvisation) while providing practical guidelines and professional training for educators, would be valuable in effective integration of musical stimulations and strategies for supporting children with dyslexia in an inclusive classroom.

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Povzetek

UDK 78:616.89-008.434.5

Prispevek obravnava, kako glasbene stimulacije podpirajo otroke z disleksijo, zlasti pri izboljšanju branja, fonološkega zavedanja in kognitivnega razvoja. Primarni cilji so identificirati učinkovite glasbene strategije, oceniti njihov vpliv in zagotoviti vključitev otrok z disleksijo v inkluzivne učilnice. Novejše raziskave poudarjajo skupne živčne mehanizme in se osredotočajo na glasbene intervencije, ki temeljijo na ritmu in melodiji ter njeni kombinaciji. Usklajene so z ustvarjanjem inkluzivnih izobraževalnih praks in podporne individualiziranega učenja. Z vključevanjem glasbenih dejavnosti v učilnice lahko učitelji razrešujejo izzive, s katerimi se soočajo učenci z disleksijo. Posebne dejavnosti v obravnavanih raziskavah vključujejo stimulacije na osnovi ritma, kot so telesna tolkala, tapkanje, bobnanje, igranje tolkal, odbijanje žoge, ki izboljšujejo fonološko obdelavo in

delovni spomin. Stimulacije, ki temeljijo na melodijah pri petju in vajah za razlikovanje tonov, izboljšajo slušno obdelavo in razumevanje jezika. Kombinirani pristopi vključujejo ritem, melodijo, veččutne elemente, gibanje, vizualne pripomočke in interaktivne digitalne tehnologije, ki skupaj krepijo asociacije z zvoki in s črkami ter tekoče branje. Te intervencije so v skladu z Gardnerjevo teorijo več inteligenc. Spodbujajo individualizirano učenje in angažma učencev. Praktične strategije za integracijo zajemajo usklajevanje glasbenih dejavnosti z bralnimi cilji, vključevanje kratkih, strukturiranih sej v redni šolski urnik ter uporabo digitalnih orodij za prilagojeno učenje in povratne informacije v realnem času, ki združujejo veččutne elemente. Programi usposabljanja učiteljev so ključni za pridobitev potrebnih veščin za učinkovito izvajanje teh strategij. Omejitve so majhne velikosti vzorcev, kratko trajanje intervencij in metodološka variabilnost, ki predstavlja izziv pri posploševanju ugotovitev. Holistične glasbene stimulacije, ki združujejo ritem in melodijo, so lahko koristne za učenje in akademsko uspešnost, osebno rast ter splošno dobro počutje učencev z disleksijo.