Academic Education Publishing House

Philosophy and Social Science Vol. 3 No. 2, 2026

Music Intervention for Speech Disorders with Autism: A Review and Strategies from an Evidence-Based Perspective

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Abstract: Autism spectrum disorder (ASD) is a neurodevelopmental condition marked by social impairments and repetitive behaviors. Speech and language disorders are a major feature of ASD and severely impact patients' ability to adapt socially. In recent years, advances in music therapy, psychology, and neuroscience have highlighted music intervention as a useful supplement for improving speech and language in individuals with ASD. Despite progress, current research faces key limitations in sample size, consistency of interventions, and outcome measure reliability. This paper reviews the literature to examine two methods—Auditory-Motor Mapping Training (AMMT) and Developmental Speech and Language Training through Music (DSLM)—and evaluates the evidence supporting them. While music interventions show potential to enhance language production and speech processing, the overall evidence remains limited. Based on these insights, this study proposes improvements, including standardized interventions, unified evaluation systems, and multicenter studies, to guide future research.

Keywords: Autism Spectrum Disorder; Music Intervention; Speech Disorders; Evidence-based Research; Music Therapy

1. Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder with early childhood onset. It is mainly identified by difficulties in social interaction, communication impairments, and repetitive behaviors [1]. In 2018, the prevalence of ASD in the United States was 2.5%. In 2019, Sun X. et al. found that the prevalence in China was rising to match European countries [2]. These figures show that ASD has become a significant public health issue globally.

As a chronic condition beginning in childhood, ASD can persistently affect social functioning and cognition without timely intervention. This can lead to severe impairments in cognition, social skills, and behavior [2]. Developing speech and language skills is essential for social adaptation, so creating effective intervention methods is a key focus in special education and psychological care. Traditional therapies include language-behavioral therapy, Picture Exchange Communication System (PECS), and key response training. However, these methods are often limited for some individuals with ASD [3-6].

Recent advances in music psychology and neuroscience have highlighted music's unique role in language and emotion. Music and language share features in rhythm, pitch, and structure, and their brain processing mechanisms overlap. This has led to the use of music intervention for treating speech disorders, which now shows promise for people with ASD.

Although studies show music intervention may improve language in individuals with ASD, research faces many methodological challenges. To address this, this study reviews the literature, analyzes methodological issues from an evidence-based angle, and proposes future strategies. The goal is to advance music intervention research with greater scientific rigor.

2. Theoretical Foundations of Music Intervention

Before focusing on specific intervention methods, it is important to briefly explain how music and language are linked cognitively and neurally. Research shows music and language overlap in acoustic structure and processing, especially in pitch, rhythm, and timing [7]. Functional imaging reveals that both the superior

temporal gyrus and the inferior frontal gyri are activated. Additionally, music training can strengthen connectivity in these regions through neural plasticity [8,9].

For individuals with ASD, this relationship is especially significant. They often have deficits in language processing, but may have strengths in some music-related skills such as pitch discrimination. Researchers have developed interventions to promote language through music, using these abilities to support weaker language skills. This gave rise to methods like "auditory-motor integration training" and "music-based developmental speech and language training." By mapping language onto musical structures, these approaches present new options for addressing speech and language impairments in ASD.

3. Mainstream Music Intervention Methods

As this field has developed, more music-based methods for addressing ASD speech disorders have appeared. Among these, AMMT and DSLM are two early examples with solid research foundations. This paper uses an evidence-based approach to systematically review and compare these interventions.

This paper identifies empirical studies of ASD music interventions using literature from CNKI, Web of Science, and PubMed. The search covered 2000 to 2025 and used terms including: "autism spectrum disorder," "music," "music intervention," "AMMT," "Auditory-Motor Mapping Training," "Developmental Speech and Language Training through Music," and "DSLM." Inclusion criteria were:

(1) children with ASD as subjects;

(2) music intervention as the main variable;

(3) clear language or speech outcome measures;

(4) controlled or pre-post design.

Exclusion criteria included: non-empirical studies (like reviews or abstracts), incomplete data or unavailable texts, and duplicate publications. Only the most complete study was kept. Table 1 presents the characteristics of included studies.

After screening and organizing the literature, this study reviews the evidence for AMMT and DSLM. It examines intervention principles, experimental design, main outcomes, and results. A special focus is placed on comparing their effects across language skill levels and contexts. The aim is to assess the effectiveness of current mainstream music interventions and to suggest improvements for future strategies.

Table 1. Basic Characteristics of the Included Studies

Included Studies	Age of Participants (years)		Sample Size		Participant Type	Control Group Intervention (Number of Sessions)	Intervention in the experimental group (number of sessions)	Outcome measures
	Control group	Experimental group	Control group	Experimental group				
Wan et al.,2011[10]	None	5~9	None	7	Non-verbal children	None	AMMT(40)	(1)
Chenausky et al.,2016[11]	3~8	3~8	7	7	Minimally verbal children	Speech Repetition Therapy(SRT)(25)	AMMT(25)	(2)(3)(4)
Chenausky et al.,2017[12]	6	4	1	1	More verbal Children	SRT(25)	AMMT(25)	(2)(3)(4)
Yan et al.,2021[13]	5	5	15	15	Nonverbal/Low-verbal children	SRT(24)	AMMT-based MMLI (Music-Mediated and Lexicon-Integrated) training)(24)	(5)(6)(7)(8)
Chenausky et al.,2022[14]	6±1	7±1	7	8	Minimally verbal children	SRT(25)	AMMT(25)	(2)(3)(4)
Lim,2007[15]	3~5		14；18	18	High/Low functioning level	No treatment；Speech treatment(6)	Developmental Speech and Language Training Through Music(DLSM)(6)	(9)
Cooley,2012[16]	3~5		4	4	High/Low functioning level	Speech treatment(2)	DSLM(2)	(10)

(1) Consonant-vowel Approximations; (2) Percent Syllables Approximately Correct; (3) Percent Consonants Correct; (4) Percent Vowels Correct; (5) Percent Initials Correct; (6) Percent Finals Correct; (7) Percent Tones Correct; (8) Percent Morphemes Correct; (9) Verbal Production Evaluation Scale (VPES); (10) Lexical Probing

3.1 Melodic Intonation Therapy and Auditory-Motor Mapping Training

Melodic Intonation Therapy (MIT) uses unison singing to help patients with speech disorders process phrases and short sentences. It helps aphasia patients regain language by chanting melodic and rhythmic parts of phrases and words [17]. In 1973, Albert et al. observed that even patients with severe left-brain damage could sing along to song lyrics. This led researchers to develop MIT. They suggested that the effect resulted from the activation of non-dominant

brain regions.

MIT was first designed for Broca's aphasia. As therapeutic techniques advanced in the 21st century, a new method appeared for those with ASD: Auditory-Motor Mapping Training (AMMT), introduced by Wan et al. in 2010. Based on the theory that mirror neurons are abnormal in autism, this intervention addresses language output problems in people with ASD [18].

In terms of implementation, the original AMMT leveraged the inherent pitch processing strengths of individuals with ASD. By using two fixed pitches generated by an electronic drum to integrate visual images, speech output, and hand movements, it gradually trained individuals with ASD to associate speech output with vocal production. The program typically consists of the following five stages: listening, unison, Unison fade, Imitation, and Cloze [11]. It has demonstrated significant intervention effects in small-scale studies that promote speech output in children with ASD [10].

Within the AMMT intervention framework, prosody serves as a key mediating variable linking music and language processing and is regarded as a crucial entry point for understanding its underlying mechanisms. Centering on this core variable, research over the past decade can be broadly divided into two developmental phases.

The first stage primarily adopted a psychological perspective, focusing on the effects of factors such as intonation training conditions, the presence or absence of intervention, and differences in participants' language abilities on phonemic processing (e.g., vowels, consonants, and syllables). Among these studies, Chenausky et al. utilized a larger sample (n=23) to further investigate the intervention effects of AMMT on children with autism and minimal language ability (mean age 6 years), comparing them with a speech repetition therapy (SRT) group of 7 participants who did not receive intonation training. The findings demonstrated that there were no appreciable differences in syllables, vowels, or consonants within the AMMT and SRT subjects. However, after excluding individuals with non-significant results at baseline and the P25 stage, the approximate syllable rate ($\chi^2(1)=10.500$, $p=.001$) and consonant accuracy ($\chi^2(1)=4.667$, $p=.031$) were significantly influenced by treatment type in the matched group, whereas no significant differences were observed for vowels ($\chi2(1)=1.167$, $p=.280$)[11]. Similarly, although their follow-up study reported a large effect size (Cohen's $d > 1.3$), the extremely small sample size (n=2) limits the stability and generalizability of the results, leaving significant uncertainty [12]. Overall, this phase consisted primarily of small-sample controlled experiments aimed at preliminarily exploring the validity of AMMT. Most studies failed to obtain stable, significant differences in overall between-group comparisons; statistical significance often emerged only after post hoc exclusion of certain participants, leaving the robustness and generalizability of the conclusions uncertain.

Research in the second phase gradually shifted from simple efficacy validation to mechanism-oriented empirical testing, expanding the research perspective from psychology to phonetics, with a focus on the structural correspondence between suprasegmental linguistic features (such as tone and intonation) and musical elements (pitch, intensity, and duration). Against this backdrop, Yan et al. conducted a relatively rigorous randomized controlled trial in a tonal language context, randomly assigning 30 children with ASD who were nonverbal or had minimal language skills to either the AMMT group or the SRT group (15 participants each) to compare intervention outcomes. The results indicated that the AMMT group, which received singing training, demonstrated greater clarity in tonal phonemes ($\chi^2(1) = 334.59$, $p < .001$; with mid-test $\beta = .22$, post-test $\beta = .61$, and follow-up test $\beta = .45$) and in terms of vocabulary output rate ($\chi^2(1) = 33.22$, $p < .001$;with immediate post-test $\beta = .247$ and delayed post-test $\beta = .103$) were significantly superior to those of the SPT group. Furthermore, these effects persisted for 2 weeks and transferred to untrained vocabulary. This study not only validated the applicability of AMMT in tonal languages to some extent but also provided empirical support for the functional link between "musical pitch and linguistic intonation" [13]. Subsequently, Chenausky et al. further examined the intervention effects of AMMT in a non-tonal language context. The study divided 14 children with ASD and severe aphasia into an AMMT group and an SRT group for comparison. The results revealed that the AMMT group also demonstrated significant improvements in vocabulary production ability [14]. These findings indicate that the intervention effects of

AMMT have evolved from early, unstable phonemic-level improvements to stable enhancements in vocabulary production and language output, demonstrating a degree of cross-linguistic applicability. Building on this foundation, research designs have become more standardized, and outcome measures have expanded from single-phoneme processing to vocabulary production and language output—which possess greater ecological validity—thereby providing more consistent empirical support for its core mechanisms.

In summary, research on AMMT has shifted from an "exploratory validation" phase toward a "mechanism-driven and function-outcome-oriented" developmental trajectory. However, from an evidence-based medicine perspective, the existing evidence still has several key limitations: First, although Phase II studies have shown greater consistency in outcome measures, the overall sample size remains limited; second, there is a lack of standardized intervention protocols and outcome assessment tools across different studies, which affects the comparability and cumulative nature of the results.

3.2 Developmental Speech and Language Training through Music

Developmental Speech and Language Training through Music (DSLM) was first proposed by Thaut [19]. Its theoretical foundation is rooted in Gestalt principles of perceptual organization, which posit that children with ASD use similar holistic processing mechanisms in the perception and production of music and language and may rely on similar cortical activation patterns, thereby enabling music to facilitate language processing. In terms of specific methods, DSLM emphasizes mapping phonemic and supraphonemic features (such as speech rhythm and intonation patterns) from language materials onto musical structures (pitch, rhythm, and harmony). By creating musicalized language materials tailored to the processing characteristics of children with ASD and utilizing singing activities, the approach aims to promote speech production and language development. Related studies indicate that the musical materials used in DSLM typically feature a limited vocal range, prominent rhythms, and clear harmonic structures to reduce processing load and enhance the perceptibility of speech information [20].

In terms of empirical research, existing DSLM studies generally follow a development path focused on exploring effects. Among these, Lin [15] studied 50 children with ASD aged 3-5 years (mean age 4 years and 8 months), randomly assigning high-functioning and low-functioning children to the "music training group," "speech training group," and "control group," respectively. The results showed that the interaction between training condition and functional level was near-significant ($F=3.142$, $p=.053$, $\eta 2=.125$). Specifically, low-functioning participants exhibited greater changes in language expression scores during music training than during speech training; in contrast, high-functioning participants demonstrated similar positive improvements under both music and speech training conditions, suggesting that musical input may have higher intervention sensitivity in participants with lower language abilities. However, in the study by Cooley et al. [16], although both the music and speech conditions showed a trend toward promoting attention and language abilities, the between-group differences did not reach statistical significance. This phenomenon of "a trend existing but evidence being unstable" is relatively common in DSLM studies, suggesting that its intervention effects still lack consistent, robust empirical support.

Based on the current evidence, DSLM offers a pathway with high ecological validity for speech intervention in ASD and demonstrates potential advantages among individuals with low functioning. However, its intervention effects still lack stable and consistent empirical support, and research paradigms have not yet established unified standards, thereby limiting the comparability and generalizability of results. Given these issues, future research should further standardize the design criteria for musical materials and incorporate larger sample sizes and rigorous controlled designs to enhance the evidence-based quality of DSLM intervention studies.

4. Exploration of Evidence-Based Strategies

Evidence-Based Medicine (EBM) emphasizes integrating the best available research evidence, professional expertise, and individual characteristics in clinical decision-making. In the fields of psychology and rehabilitation, this concept has evolved into Evidence-Based Practice (EBP) and has gradually become a

crucial methodological framework for intervention research. In this context, Zhang Xiaoyuan et al. [21] systematically elaborated on its application background and objectives: "When third parties began to cover the costs of psychotherapy, a strong demand for accountability and oversight of the psychotherapy process emerged... The adoption of evidence-based approaches in psychotherapy has also become an inevitable reform resulting from the need to secure its legitimate status within the modern healthcare economic landscape." Furthermore, recent meta-research has increasingly highlighted that issues of reproducibility, transparency, and methodological rigor remain central challenges in clinical and behavioral sciences, reinforcing the importance of evidence-based approaches in improving research credibility and clinical accountability [22,23].

A review of the existing literature reveals that current research on music interventions for ASD primarily faces the following three methodological issues. From an evidence-based perspective, while existing studies in the field of music interventions for speech disorders in ASD have provided preliminary empirical support, the overall evidence base remains at a relatively early stage of development. Specifically, current research exhibits structural deficiencies in evidence quality, intervention consistency, and the standardization of outcome measures.

4.1 Sample Size Issues

According to the EBM evidence grading system, high-quality evidence typically relies on large-sample randomized controlled trials (RCTs) or systematic reviews [24]. However, existing music intervention studies primarily rely on small-sample experiments or exploratory controlled studies, with sample sizes typically ranging from single digits to several dozen; only a few studies have reached moderate sample sizes.

Insufficient sample size directly impacts statistical power, increases the risk of Type II errors (false negatives), and renders study results highly sensitive to individual variability. For example, in AMMT studies, some significant results were evident only after post hoc exclusion, whereas DSLM studies frequently yielded "marginal significance" or non-significant results.

Furthermore, small-sample studies struggle to support subgroup analyses (e.g., differences in functional levels or language types), thereby limiting the clear definition of the intervention's applicability. Consequently, the overall evidence in this field remains at a low to moderate level (Level II-III), and its generalizability and clinical guidance value still need improvement.

Finally, to elevate the level of evidence, future studies should prioritize multi-center randomized controlled trials (RCTs) to expand sample sizes and enhance statistical power. Concurrently, a priori power analysis should be conducted during the study design phase to avoid relying on post hoc selection to achieve significant results. Furthermore, the validity of subgroup analyses can be enhanced through stratified randomization (e.g., by functional level or language proficiency), thereby more precisely defining the target population for intervention.

4.2 Issues of Intervention Heterogeneity

EBP emphasizes the replicability and fidelity of interventions, which are prerequisites for accumulating evidence and enabling cross-study comparisons [25]. However, in existing music intervention studies, intervention protocols generally lack uniform standards, particularly regarding the design of musical materials and implementation procedures.

Taking DSLM as an example, its core intervention relies on mapping linguistic features to musical structures; however, the design of specific musical materials (such as pitch range, rhythmic complexity, and harmonic structure) largely depends on the experiential judgment of researchers or therapists, lacking operationalization criteria. Similarly, in AMMT studies, there are variations across studies in pitch selection, rhythmic presentation, and training procedures. This intervention heterogeneity directly hinders cross-study comparisons or meta-analyses.

From an evidence-based medicine perspective, a lack of standardization in interventions weakens internal and external validity and makes it difficult to conduct systematic reviews or meta-analyses, thereby limiting the translation of evidence to higher levels of practice.

To address the issue of intervention heterogeneity, it is recommended to establish a standardized intervention framework based on existing methods, including:

(1) Defining parameters of musical materials (pitch range, rhythmic structure, harmonic

complexity)
(2) Standardizing the training process (e.g., phase division and training frequency)
(3) Standardizing the treatment manual
Additionally, the intervention process should be systematically described in accordance with the TIDieR (Template for Intervention Description and Replication) reporting guidelines to enhance the replicability and transparency of the research.

4.3 Issues Regarding Outcome Measures

Within the framework of evidence-based medicine, consistency in outcome measures is key to enabling cross-study comparisons and meta-analyses [26]. However, current music intervention studies exhibit significant heterogeneity in the selection of outcome measures.
Specifically, there are significant differences in the level of measurement across studies: some focus on phonetic segments (e.g., accuracy rates for vowels and consonants), while others concentrate on higher-level language functions (e.g., vocabulary production or communication skills). Furthermore, the lack of standardized measurement tools, coupled with inadequate reporting of effect sizes and confidence intervals (CIs), further limits the precision of result interpretation.
Previous research has indicated that the absence of a core outcome set significantly increases inconsistency among studies and weakens the ability to synthesize evidence. This issue is particularly pronounced in the field of music intervention, making it difficult to build cumulative evidence across studies and limiting the systematic validation of intervention mechanisms.
To enhance comparability across studies, future research must establish a unified core outcome set, including:
Basic level: Phonemic processing (vowels, consonants, syllables)
Functional level: Vocabulary generation and language production abilities
Extended level: Communication skills and social interaction performance
Furthermore, statistical reporting should be standardized to systematically provide effect sizes and confidence intervals, and follow-up assessments should be incorporated to evaluate the sustainability and generalizability of intervention effects. By establishing a standardized outcome framework, the ability to synthesize evidence can be significantly enhanced, laying the groundwork for meta-analyses.

5 Conclusion

Based on the perspectives of evidence-based medicine (EBM) and evidence-based practice (EBP), this study conducted a systematic review and comparative analysis of two representative music-based intervention methods for speech disorders in autism spectrum disorder: AMMT and DSLM. The results indicate that research on AMMT has gradually shifted from early exploratory validation to mechanism-oriented empirical studies. Its promotional effects on vocabulary generation and language output have gradually gained relatively consistent evidence in support and demonstrate a certain degree of cross-linguistic applicability. In contrast, DSLM remains largely in the exploratory stage; although it shows potential for intervention in low-functioning populations, its effects still lack stable, consistent empirical support.
From an evidence-based medicine perspective, current research is primarily constrained by three methodological limitations: insufficient sample sizes limit statistical power and the level of evidence; a lack of standardized intervention protocols reduces the reproducibility of studies; and inconsistent outcome measures hinder the integration and comparison of evidence. These issues have, to some extent, hindered the transition from exploratory research to high-quality evidence-based practice in this field.
Future research should prioritize advancing multicenter randomized controlled trials, developing standardized intervention systems, and establishing a unified framework of core outcome measures to enhance the standardization and comparability of studies. Overall, music intervention holds significant potential for application in speech rehabilitation for ASD, but its translation into evidence-based practice with clear mechanisms and robust evidence remains dependent on more rigorous, systematic research designs.

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