Ritter, M. J., et al., (2026). *J Commun Disord Treat, 1*(1): 102
https://doi.org/10.33790/jcdt1100102

Journal of Communication Disorders and Treatment

The Impact of Interactive Metronome Training on Literacy and Narrative Skills for School-Aged Children

Michaela J. Ritter, Ed.D, CCC-SLP, Sandra E. Wright*, Ph.D., CCC-SLP, and Diane Loeb, Ph.D., CCC-SLP
Speech Language Pathologist, Baylor University, United States.

Article Details
Article Type: Research Article
Received date: 05th February, 2026
Accepted date: 17th April, 2026
Published date: 20thApril, 2026

***Corresponding Author:** Sandra Wright, Ph.D., CCC-SLP, Speech Language Pathologist, Post Doctoral Fellow, Baylor University, United States.

Citation: Ritter, M. J., Wright, S. E, & Loeb, D. (2026). The Impact of Interactive Metronome Training on Literacy and Narrative Skills for School-Aged Children. *J Commun Disord Treat, 1*(1): 102. doi: https://doi.org/10.33790/jcdt1100102

Abstract

This study examined the effectiveness of incorporating Interactive Metronome (IM) training into language and reading interventions for improving language and literacy skills in school-age children with co-occurring developmental language disorder (DLD) and reading impairments. Sixty-six monolingual English-speaking children (ages 5–16) with language and reading impairments participated; those with suspected intellectual disability, neurological, hearing, or physical impairments were excluded. Participants were randomly assigned to an IM or control group. Both received four weeks of daily language and literacy instruction, with the IM group completing an additional 15 minutes of IM training four times weekly. Pre- and post-intervention data were collected using the Woodcock Reading Mastery Test–III (Woodcock, 2011) by blinded research assistants. Independent t-tests and repeated-measures ANOVAs revealed a significant group difference in oral reading fluency post-intervention, favoring the IM group. No significant differences were observed for narrative production or reading comprehension. Supplementing traditional language and literacy intervention with IM produced significant gains in oral reading fluency compared to intervention alone. These findings suggest that IM may enhance timing, rhythm, and perceptual skills underlying reading fluency. Further research should investigate longer intervention durations and advanced IM phases to determine their potential effects on broader literacy outcomes.

Keywords: Reading Fluency, Reading Comprehension, Language Intervention

Introduction

Children with developmental language disorder (DLD) are at significantly greater risk of reading difficulties than their typically developing peers, with estimates suggesting they are five to six times more likely to struggle with reading acquisition [1-3]. Deficits often span morphology, syntax, phonological processing, semantics, and pragmatics, and frequently parallel impairments in written language and literacy skills [4-8]. Slowed auditory information processing is thought to underlie these challenges, limiting phonological representation development and impairing skills such as phonological awareness and decoding [2, 5, 7, 8].

Timing and rhythm are also critical for fluent reading and comprehension [9-14]. Deficits in rapid automatized naming, phonological processing, and temporal auditory perception have been linked to persistent reading impairments [10, 11, 14-20]. Disruptions in these processes hinder automatic grapheme–phoneme mapping, slowing reading fluency and affecting comprehension [16]. Zanto and colleagues [13] conducted a study to improve reading and math fluency using a digital rhythm training game. They found that the only improvements from their timing game were in reading fluency, with no improvements in math fluency.

Interactive Metronome (IM) is a computer-based intervention targeting timing and rhythm through synchronized motor responses to auditory beats with real-time feedback [21]. The real-time feedback is received using either a handheld switch or a foot pad that the client steps on to activate. When the participant activates a switch then a buzzer sound is made to provide feedback on how close they are to the designated timing target. The timing target consisted of a beep-like auditory signal, similar to the ticking of a clock's second hand.Participants progressed through multiple response phases, including activating the switch in the right hand on their right hip, to a clapping motion with the switch on the right hand but the hands coming together to activate the switch, to alternating toes tapping on the tap mat, and other combinations. There is a goal of task accuracy of activating the buzzer in sync with the timing target before moving on to a new level of patterns. IM has been applied across populations to improve timing for tasks such as walking, handwriting, and reading [10, 17, 18, 22, 23]. In literacy contexts, IM has been shown to improve reading fluency, rate, and comprehension [10, 17].

However, existing studies on IM for children with DLD and reading impairments are limited by small sample sizes, lack of randomization, and inconsistent outcome measures, making it difficult to determine efficacy. Although the American Speech-Language-Hearing Association (ASHA) lists IM as a potential intervention for timing, coordination, and attention, additional controlled research is needed to guide evidence-based practice.

Given the limited and methodologically variable research on IM for children with DLD and reading impairments, this study aimed to determine whether adding IM to a traditional language and reading intervention would yield greater gains in key literacy and narrative skills than traditional intervention alone. Specifically, we examined whether school-age children receiving IM demonstrated significantly greater pre- to post-treatment improvements in (a) reading fluency, (b) reading comprehension, (c) narrative production, and (d) narrative comprehension.

Materials and Methods

Participants

The study protocol was reviewed and approved by the university's Institutional Review Board. All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional research committee and the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Written parental consent and child assent were obtained prior to participation. All participants were administered standardized reading and language assessments by a graduate student in communication sciences and disorders, supervised by a certified speech-language pathologist (SLP), to determine eligibility. Inclusion criteria were: (a) documented reading impairment and developmental language disorder, (b) normal hearing as confirmed by screening, (c) no intellectual disability, and (d) monolingual English speakers.

A total of 66 children met the inclusion criteria and were randomly assigned to the IM treatment group (n = 33) or a control group (n = 33). The IM group included 14 males and 19 females (ages 5;0 to 12;9, *M* = 7;8, *SD* = 2;0). The control group included 18 males and 15 females (ages 5;5 to 15;3, *M* = 9;2, *SD* = 2;5). Groups were not matched for age due to randomization. Across both groups, 41 participants were Caucasian, 4 African American, 8 Hispanic, 3 Pacific Islander/Native Hawaiian, 1 "other," and 9 did not report. Families were primarily from lower- to middle-class backgrounds based on parent self-report.

Assessments

All participants completed a pre-intervention battery that included the Woodcock Reading Mastery Test–III (WRMT-III) [14] for literacy skills and the ghost story picture from the Test of Narrative Language–2nd Edition (TNL-2) [25] to assess language and narrative skills. Narrative samples were scored and analyzed for story grammar elements (character, setting, initiating event, internal response, plan, attempts, direct consequence, resolution/feelings) and total T-units. Post-intervention testing used the same measures and scoring procedures.

Procedures

Baseline testing occurred 1–2 weeks before intervention. Following the 4-week intervention, post-testing was completed using the same standardized protocols. Certified SLPs administered all standardized measures, and trained graduate students, supervised by licensed SLP faculty, administered non-standardized narrative measures. Assessment sessions lasted 60–90 minutes. All assessors and scorers were blinded to group assignments. Participants were assigned numeric codes to maintain confidentiality, and test administration order was consistent across participants.

Reliability and Fidelity

All measures were administered and scored in accordance with their manuals by certified speech-language pathologists. Scoring accuracy was verified by two independent graduate research assistants, with initial agreement ranging from 90.7% to 94.2% (M = 92.45%). Discrepancies were resolved through consensus to achieve 100% agreement.

Intervention

All participants attended a summer practicum program, receiving 165 minutes of daily language and literacy instruction, Monday through Thursday, for four weeks. Intervention included three 50-minute segments:

1. **Phonology, Semantics, Syntax, and Morphology** – phonological awareness, vocabulary (synonyms, antonyms, analogies), semantics, and syntax.
2. **Expository and Narrative** – narrative structure instruction and text structure strategies to support comprehension and written/oral expression.
3. **Reading** – reading fluency, decoding, and comprehension tasks.

The only difference between groups occurred in a 15-minute daily block: the IM group completed IM therapy, while the control group engaged in snack time and short story reading.

Interactive Metronome Program

IM is a computer-based timing intervention consisting of a master control unit, headphones, a hand trigger, and a footpad [21]. Participants synchronized clapping or toe taps to a reference tone delivered through headphones, receiving auditory and visual feedback. All clinicians held IM certification.

The IM program followed five progressive phases:

- **Phase I** – Basic motor synchronization without feedback.
- **Phase II** – Introduction of guide sounds for timing accuracy (buzzer = early/late, gong = slightly early/late, bell = on-time).
- **Phase III** – Mastery of timing and rhythm to age-based task goals. See Table 1.
- **Phase IV** – Generalization to attention, academic, and motor tasks.
- **Phase V** – Crossover tasks involving opposite limb coordination and external stimuli.

Age in years	Task Average Criteria
6	90-119
7-8	65-89
9-10	55-79
11-12	45-74
13-15	43-71
16+	41-69

Table 1: Average Criteria by age for Interactive Metronome Tasks in Milliseconds [21].

Exercises (both hands, right/left hand, both toes, right/left toe) were included in each phase, with duration, feedback, and cueing adjusted for individual performance [18]. Progression through phases was based on skill acquisition, with some participants requiring up to four sessions to advance beyond Phase I.

Results

Baseline Comparisons

Independent sample t-tests were conducted to examine baseline differences between the IM and control groups on all pre-intervention measures. Group (IM vs. control) was the independent variable, and each narrative element was analyzed separately. No significant differences were found for any narrative element prior

to intervention, indicating that randomization was successful in producing comparable groups. Pre-intervention narrative element scores are presented in Figure 1. Comparisons of the WRMT-III [24] subtest scores at pretest are shown in Figure 2.

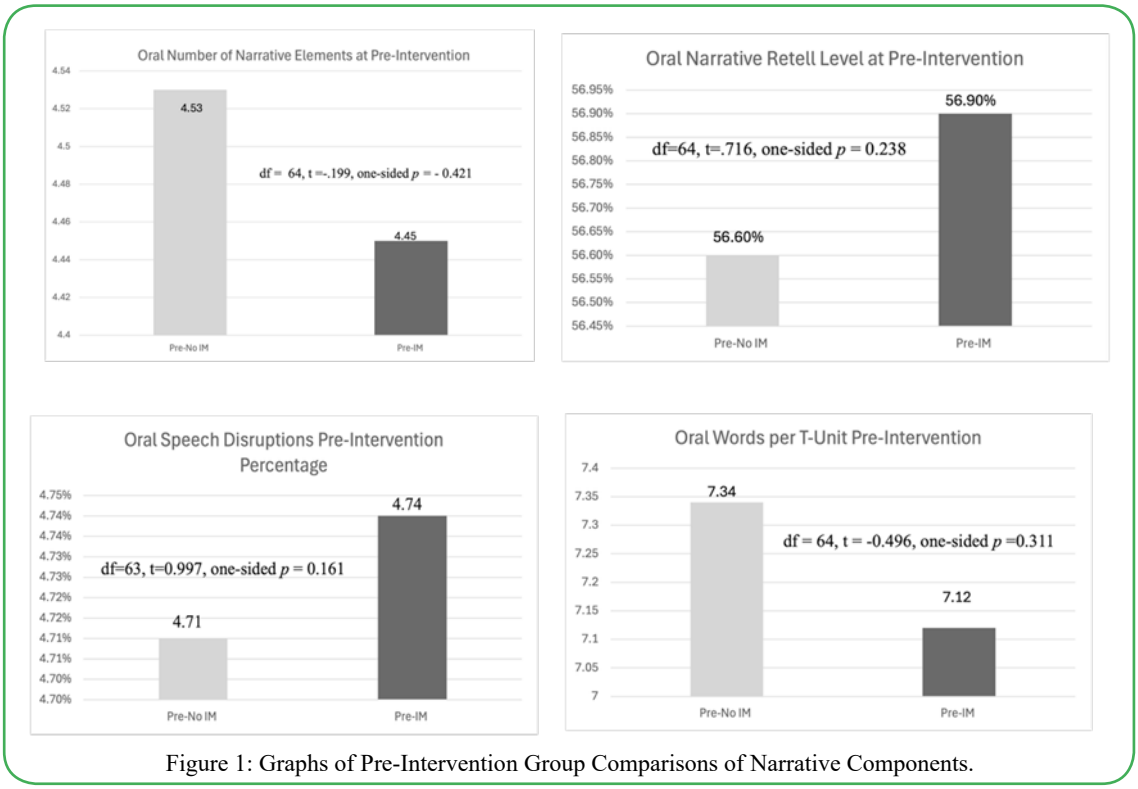

Figure 1: Graphs of Pre-Intervention Group Comparisons of Narrative Components.

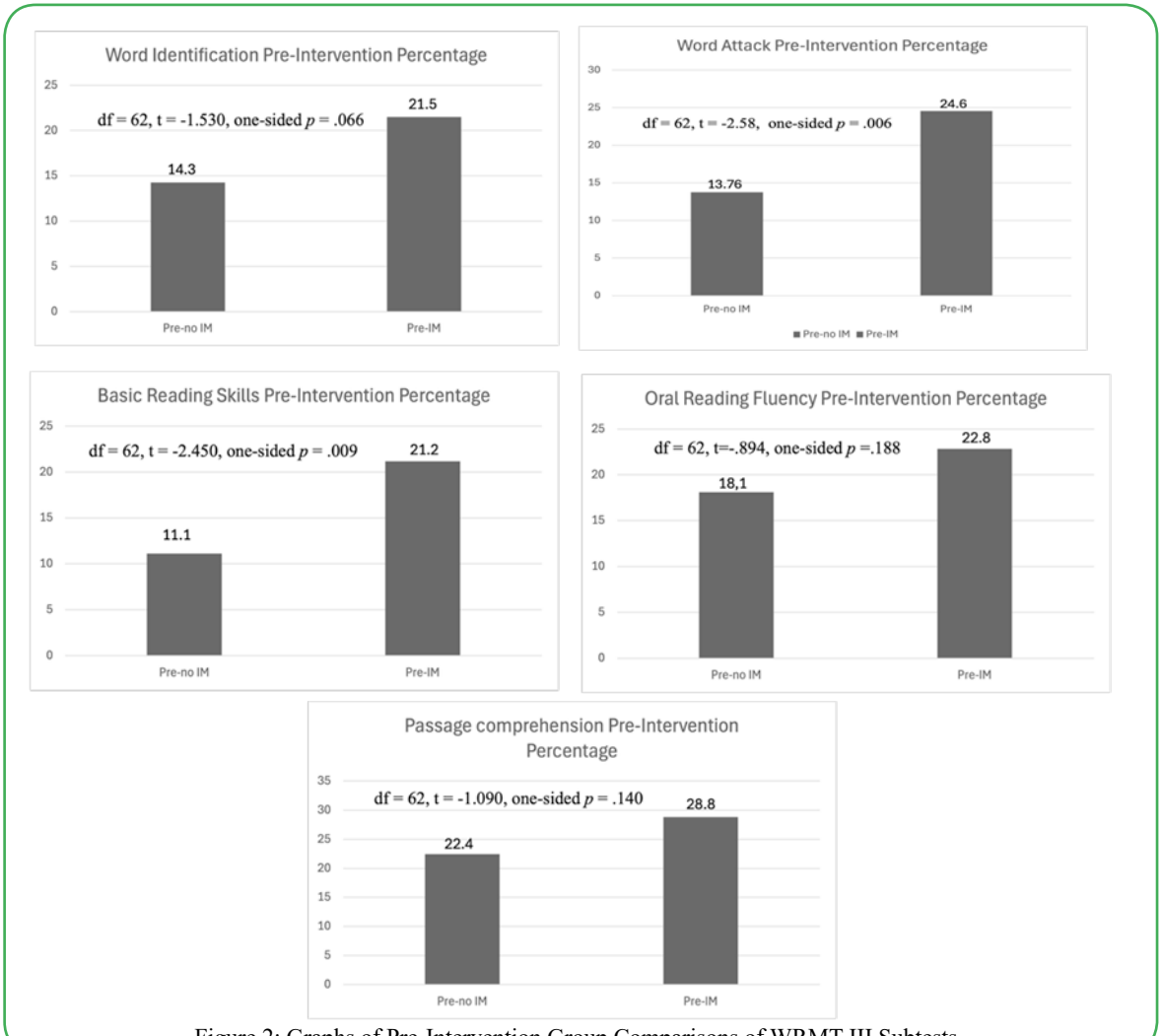

Figure 2: Graphs of Pre-Intervention Group Comparisons of WRMT-III Subtests.

Narrative Outcomes

Post-intervention narrative data were analyzed using independent sample t-tests with group as the independent variable and each narrative measure as the dependent variable. One-tailed tests were used, given the directional hypothesis that the IM group would demonstrate greater improvement. Although none of the differences reached statistical significance, descriptive statistics and effect sizes (Cohen's d) are reported in Table 2.

Pairings	df	t-value	One-sided p	Cohen's d
Oral Number of Narrative Elements	64	-0.758	0.226	-.187
Oral Narrative Retell Level	64	-0.365	0.358	.090
Oral Speech Disruptions Percentage	64	0.831	0.205	.204
Oral Words per T-Unit	64	-0.217	0.414	-.054

Table 2: Post-intervention narrative element comparisons between IM and control groups, with effect sizes.

Note. Narrative language components were measured using either t-units or a subtest from the Test of Narrative Language-Second Edition [25].

Reading Outcomes

A repeated-measures analysis of variance (ANOVA) with a Greenhouse–Geisser correction was conducted to evaluate changes in reading skills over time between groups. Group (IM vs. control) served as the between-subjects factor, and time (pretest, posttest) was the within-subjects factor for each WRMT-III subtest. Results are summarized in Table 3.

Pairing	F	p	Partial Eta Squared	Effect size
Oral Reading Fluency IM*	1, 105.31=4.26	0.043	.064	Small
Oral Reading Fluency No-IM	1, 52.26 = 2.12	0.15	.033	Small
Word Identification IM	1, 21.45 = .31	0.10	.000	Trivial
Word Identification No-IM	1, 0.003 = .000	0.58	.005	Trivial
Word Attack IM	1, 80.96 = .684	0.41	.011	Trivial
Word Attack No-IM	1, 47.95 = .405	0.53	.006	Trivial
Basic Reading Skills IM	1, 14.41 = .284	0.60	.005	Trivial
Basic Reading Skills No-IM	1, 0.870 = .017	0.90	.000	Trivial
Paragraph Comprehension IM	1, 65.00 = .406	0.53	.007	Trivial
Paragraph Comprehension No-IM	1, 60.93 = .381	0.54	.006	Trivial

Table 3: Repeated-measures ANOVA results for WRMT-III subtests, comparing IM and control groups.

Note: The asterisk indicates a significant finding.

Discussion

The comorbidity of language and reading impairments is well-documented [1-3, 26, 27]. This study examined whether supplementing traditional language and literacy intervention with IM for 15 minutes, four times per week over four weeks, would improve reading fluency, reading comprehension, narrative production, and narrative comprehension in school-age children with DLD and reading impairments. While prior research using IM shows that rhythm and timing increases reading rate and comprehension, this study only demonstrated an impact on overall reading fluency.

Findings indicated that IM produced a significant improvement in reading fluency but not in narrative abilities when compared to the control group. This supports prior work suggesting that IM and rhythmic input can positively influence reading fluency and comprehension [13, 17] and may be related to its targeted enhancement of perceptual skills essential for reading, including timing, rhythm, auditory perception, and visual perception [5, 7, 8]. The impact on reading fluency observed in this study may reflect the early integration of these perceptual skills into the automatic working system, which had not yet generalized to other reading domains such as word identification, word attack, or paragraph comprehension [18].

IM's repetitive, rhythmic tasks may support sustained attention, a critical skill for reading, where maintaining concentration over extended periods is necessary for comprehension and information retention. Improvements in cognitive processing speed, fostered by temporal processing gains, may facilitate stronger connections between ideas and more efficient parsing of complex sentences. By addressing the foundational skills of timing, rhythm, attention, and cognitive processing. IM may serve as a valuable adjunctive intervention for students with reading impairments. Clinically, IM may also offer a beneficial means of improving reading fluency through a mechanism that is distinct from direct engagement with printed text, thereby providing a useful supplemental avenue for intervention.

Limitations

Several limitations should be noted. First, progression through IM phases [21] varied among participants, resulting in inconsistent levels of visual and auditory feedback across the IM group. Second, the relatively short intervention period (16 sessions) may have limited the opportunity for perceptual skill gains to generalize to broader reading and narrative outcomes. Notably, some participants had only reached or just surpassed Phase II by the study's conclusion, potentially restricting their exposure to higher-level IM tasks that may support transfer to literacy and narrative measures. Finally, the inability to match participants based on age due to the variability based on randomization of participants into the control and experimental groups.

Directions for Future Research

Future studies should explore whether increasing the duration to 32 or more sessions enhances outcomes in word identification, word

attack, paragraph comprehension, and narrative abilities. Research should also investigate the effects of controlled advancement of IM phase, with controlled feedback, compared to standard clinician-guided progression. Additionally, incorporating concurrent attention and sequencing tasks (e.g., reciting the alphabet or days of the week in sync with the IM tone) may further strengthen the link between perceptual timing skills and reading outcomes.

Conclusion

This study adds to the growing body of evidence supporting the role of temporal processing interventions in reading development for children with developmental language disorder and reading impairments. Supplementing traditional language and literacy instruction with 15 minutes of IM training, four times per week over four weeks, significantly improved reading fluency but did not yield measurable gains in narrative production or comprehension. These findings suggest that IM's targeted enhancement of timing, rhythm, auditory perception, and visual-motor integration may facilitate the development of automaticity in reading fluency before transferring to broader literacy domains.

For clinical practice, IM may serve as a viable adjunct to conventional interventions for improving reading fluency in school-age children with combined language and reading difficulties. However, longer intervention durations, standardized progression protocols, and integration of attention and sequencing tasks may be necessary to produce broader gains in comprehension and narrative abilities. Future research should refine IM protocols and investigate their potential for supporting multiple components of literacy.

Conflict of Interest Declaration: The authors declare that they have no affiliations with or involvement in any organization or entity with any financial interests in the subject matter or materials discussed in this manuscript.

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