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Rhythmic Skills and Reading Performance in Brazilian Primary School Children: Evidence from a Low-SES Context

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Abstract

Rhythm organizes events in time and has been associated with phonological and reading development. However, little is known about whether rhythmic skills are shaped by the same environmental factors that influence children's reading performance. This study investigated associations among socioeconomic status (SES), parental involvement in school routines, extracurricular activities, rhythmic skills, and reading outcomes in Brazilian primary school children. Participants were 226 children in 1st to 3rd grade attending a public school in Embu das Artes, São Paulo, Brazil. Children completed measures of word and pseudoword reading, reading comprehension, rhythm perception, and rhythm reproduction. Parents reported family income, parental education, parental involvement in school routines, and children's participation in extracurricular activities. Spearman correlations, mediation models, and moderation models were conducted. Family income and parental involvement were positively associated with reading outcomes, but not with rhythmic skills. Parental involvement did not mediate the association between SES and reading. Participation in musical extracurricular activities did not moderate the association between SES and rhythmic skills. Rhythm reproduction was positively associated with word and pseudoword reading. These findings suggest that, in this sample, rhythmic skills were less directly associated with measured socioeconomic variation than reading outcomes, and may warrant further investigation as a potential target for future reading-related interventions.

Introduction

Reading development results from the interaction among three interdependent levels: (1) the behavioral level, which concerns children's observable performance on school-related tasks; (2) the level of individual characteristics, which includes cognitive factors, such as memory and phonological awareness, and psychosocial factors, such as motivation and emotional self-regulation; and (3) the neurobiological and environmental level, which includes genetic and structural predispositions as well as contextual variables, such as socioeconomic status (SES), quality of school instruction, and the family environment (Fletcher et al., 2007, 2018). In contexts marked by social inequality, this framework is useful for understanding how individual and environmental factors are associated with reading development and for identifying accessible pathways for educational intervention.

At the individual level, phonological processing, rapid access to verbal representations, attention, and working memory are well-established contributors to reading development. Evidence from Brazilian children has similarly highlighted phonological awareness, rapid automatized naming, and working memory as relevant predictors of reading performance (Lima et al., 2020; Placiteli & Barrera, 2023; Silva et al., 2025).

At the environmental level, children's development is shaped by contexts such as their home, family, and school, as well as broader socioeconomic indicators, including parental occupation, education, and income. Evidence shows that SES is associated with children's academic performance, through factors

such as school quality, access to resources, and family interactions (Bonifacci et al., 2020; G. Li & Christ, 2007), and with cognitive abilities more broadly (Piccolo et al., 2016).

One pathway through which SES may relate to reading performance is the family environment. According to the family investment model (Conger & Donnellan, 2007), families with greater socioeconomic resources may have more opportunities to invest material and nonmaterial resources in children's development. These investments may include access to books and educational materials, literacy-related experiences, cultural activities, support for school routines, and time devoted to learning activities. Thus, socioeconomic conditions may be associated with reading not only through material resources but also through family practices and opportunities for learning.

Parental involvement is a broad construct that includes behaviors, beliefs, expectations, and attitudes related to children's academic development. In reading, it may involve monitoring homework, communicating with the school, identifying academic difficulties, encouraging reading, and valuing schooling. Previous studies have shown that parental involvement in school routines is associated with better literacy skills (Fortaleza & Lomarda, 2025; Silinskas et al., 2020). Therefore, examining parental involvement may help clarify whether family practices partly explain the association between SES and reading.

Beyond the cognitive and environmental factors more commonly examined in reading research, musical rhythm has received increasing attention because it shares temporal and auditory processing demands with language. Music and language both require the perception and organization of sound patterns over time, and rhythmic processing has been linked to phonological and reading-related skills (Fujii & Wan, 2014; Schön & Tillmann, 2015; Torppa & Huotilainen, 2019). Children with dyslexia, for example, have been shown to experience difficulties in rhythmic and temporal processing (Huss et al., 2011; Overy et al., 2003). The construct of rhythm may capture partially distinct processes: rhythm perception and rhythm reproduction. Whereas rhythm perception relies on auditory discrimination and temporal pattern detection, rhythm reproduction additionally involves auditor-motor mapping, timing, working memory, and motor synchronization.

Consistent with this theoretical overlap, associations between rhythm perception and reading performance have been reported in several studies (Flaugnacco et al., 2014; Huss et al., 2011; Lê et al., 2020; Ozernov-Palchik & Patel, 2018). However, the mechanisms underlying this relationship remain unclear, especially in economically vulnerable contexts where children may face greater educational and socioeconomic barriers. This limitation is particularly important because most evidence on socioeconomic influences in reading has focused on family and educational factors, whereas less is known about whether these same contextual factors are associated with rhythmic skills. Although SES and the family environment are well-established correlates of reading, it remains unclear whether rhythmic abilities are shaped by socioeconomic inequalities in the same way as reading outcomes.

Beyond regular school hours, many children participate in extracurricular activities (ECAs), that is, structured activities outside the school schedule aimed at leisure, cultural development, or academic

improvement. Participation in ECAs has also been examined in the literature, with evidence suggesting positive effects on general academic performance in elementary school children, especially in mathematics, languages (native and foreign), science, and arts (Alvariñas-Villaverde et al., 2024), as well as on socioemotional skills (Carbonaro & Maloney, 2019), although there is no consensus regarding the type, amount, and duration of such activities. Because access to structured extracurricular activities may also vary by SES, ECAs were examined as a complementary environmental factor.

Current Study

The present study examined associations among SES, parental involvement in school activities, participation in extracurricular activities (ECAs), reading performance (word and pseudoword reading, and comprehension), and rhythmic skills (perception and reproduction) in Brazilian children in the early years of elementary school. Specifically, we tested whether (1) SES, parental involvement, and ECAs were associated with reading and rhythm outcomes; (2) parental involvement mediated the relation between SES and reading; and (3) rhythmic skills were associated with reading. As an exploratory moderation analysis, we examined whether musical ECAs moderated the association between SES and rhythmic skills.

We expected SES to be positively associated with reading outcomes, partly through parental involvement. We also hypothesized that rhythmic skills would vary according to SES and that this association would be moderated by participation in musical ECAs. Finally, we expected rhythmic skills to be positively associated with reading.

By focusing on children from an economically vulnerable context, this study may help clarify whether rhythmic skills are shaped by socioeconomic factors in the same way as reading outcomes and whether rhythm-based skills may be worth investigating as potential targets for future reading-related interventions.

Method

Design

This study used a prospective three-wave correlational design to test mediation hypotheses, ensuring predictors preceded mediators and outcomes. Predictor variables (sociodemographic characteristics) were collected in Phase 1 (March–June 2024), the mediator (parental involvement) in Phase 2 (October–November 2024), and outcomes (reading and rhythm measures) in Phase 3 (October–November 2025). The study was conducted in a public elementary school in Embu das Artes, São Paulo, Brazil, with ethics approval (CAAE: 63658122.1.0000.5336).

Participants

Initially, 259 children were eligible for participation. Of these, 24 were excluded due to syndromic, neurological, or psychiatric conditions, or IQ ≤ 70, as assessed with the Wechsler Abbreviated Scale of Intelligence (Yates et al., 2006). Of the remaining 235 children, 9 transferred to another school after the first assessment, resulting in a final sample of 226 participants (73 in 1st grade, 71 in 2nd grade, and 82 in 3rd grade). The mean age was 7.08 years (*SD* = 0.85), and 54.4% of the sample was female (Table 1).

Inclusion criteria were: (a) Brazilian Portuguese as the native language; (b) no hearing or neurological impairments, according to parent report; (c) normal or corrected-to-normal vision; and (d) estimated IQ ≥ 70.

Regarding family characteristics, parental education was predominantly at the high school level or below (Table 1). Most mothers (80%) and fathers (89%) had completed no more than high school. Moreover, the sample was concentrated in lower income ranges. In 2024–2025, the Brazilian monthly minimum wage was approximately R$ 1,400–1,500 (≈ USD 280–300). Overall, 31% of families reported an income of up to one Brazilian monthly minimum wage, and 35% reported an income between one and two minimum wages; thus, 66% of the sample had a family income of up to two minimum wages. The most common household composition was three to four people (67%), followed by five to six people (18%).

Table 1

Sample Characteristics for the Total Sample and by School Grade

Sample characteristics	***n* (%)**				
		Total ***N* = 226**	**1st grade** ***n* = 73**	**2nd grade** ***n* = 71**	**3rd grade** ***n* = 82**
Child characteristics					
Sex	Male	103 (46)	34 (47)	29 (41)	40 (49)
	Female	123 (54)	39 (53)	42 (59)	42 (51)
Age	Mean	7.08	6.03	7.1	8.01
	SD	0.85	0.16	0.3	0.11
IQ	Mean	94.4	95.67	95.59	92.24
	SD	11.84	11.29	12.61	11.47
Family characteristics					
Maternal education (*n* = 162)	No formal instruction	3 (2)	-	1 (2)	2 (4)
	Primary education [1]	11 (7)	-	5 (10)	6 (11)
	Lower secondary education [2]	9 (6)	4 (7)	2 (4)	3 (5)
	Upper secondary education [3]	106 (65)	39 (68)	31 (65)	36 (63)
	Higher education [4]	29 (18)	11 (19)	8 (17)	10 (18)
	Postgraduate education	4 (2)	3 (5)	1 (2)	-
Paternal education (*n* = 146)	No formal instruction	3 (2)	1 (2)	-	2 (4)
	Primary education [1]	13 (9)	2 (4)	6 (15)	5 (9)
	Lower secondary education [2]	26 (18)	7 (14)	6 (15)	13 (24)
	Upper secondary education [3]	87 (60)	28 (56)	27 (66)	32 (58)
	Higher education [4]	13 (9)	9 (18)	2 (5)	2 (4)
	Postgraduate education	4 (3)	3 (6)	-	1 (2)
Socioeconomic data					

Sample characteristics	*n* (%)				
		Total ***N* = 226**	**1st grade** ***n* = 73**	**2nd grade** ***n* = 71**	**3rd grade** ***n* = 82**
Child characteristics					
Family income (*n* = 159)	Up to 1 minimum wage	49 (31)	15 (27)	19 (41)	15 (26)
	1 to 2 minimum wages	56 (35)	18 (32)	15 (33)	23 (40)
	3 to 4 minimum wages	42 (26)	19 (34)	9 (20)	14 (25)
	5 to 6 minimum wages	9 (6)	3 (5)	2 (4)	4 (7)
	7 to 10 minimum wages	3 (2)	1 (2)	1 (2)	1 (2)
Household composition (*n* = 164)	2 people	19 (12)	7 (12)	6 (13)	6 (10)
	3 to 4 people	110 (67)	38 (67)	33 (69)	39 (66)
	5 to 6 people	29 (18)	10 (18)	8 (17)	11 (19)
	7 to 8 people	5 (3)	1 (2)	1 (2)	3 (5)
	9 or more people	1(1)	1(2)	-	-

Brazilian educational levels correspond approximately to: 1. Grades 1–5; 2. Grades 6–9; 3. Grades 10–12; 4. Bachelor's degree or equivalent.

Note

Socioeconomic data were obtained from the sociodemographic questionnaire completed by parents. The number of observations differs across variables because some questionnaires were returned with blank responses.

Instruments

Predictors

- **Sociodemographic and extracurricular activity questionnaire**: Sociodemographic variables were obtained through a questionnaire completed by children's parents or legal guardians. For the present study, information on maternal education, paternal education, family income, and household composition were used.

Maternal and paternal education were recorded as ordinal categories ranging from no formal education to graduate education, and family income was reported in ranges of Brazilian monthly minimum wages.

An aggregate SES indicator was created using principal component analysis with maternal education and family income, representing complementary educational and material dimensions of socioeconomic conditions. Parental education is commonly used as an indicator of socioeconomic position because it is associated with cognitive and academic development through pathways involving parental beliefs, educational expectations, and the home learning environment (Bradley & Corwyn, 2002). Maternal education was selected as the educational component because previous research has identified it as a particularly robust correlate of children's cognitive and academic development, including early reading development (Muñez et al., 2022). In the present sample, maternal education also had greater data availability than paternal education, reducing the loss of observations when constructing the composite SES indicator. Moreover, the composite SES index was created to reduce multicollinearity and provide a more stable predictor for mediation and moderation models (J. Li et al., 2023).

A one-component solution was retained, explaining 66.18% of the total variance, with equivalent loadings for maternal education and family income (.81 for both variables; eigenvalue = 1.32). Bartlett's test of sphericity was significant, $\chi^2(1) = 17.10$, $p < .001$. Higher component scores indicated higher SES. Because the PCA included only two indicators, the component was interpreted as a pragmatic composite SES index.

Mediators/Moderators

- **Checklist of shared routines and family-school involvement (preliminary shortened version)** (Dessen & Polonia, 2009): This questionnaire assesses caregivers' involvement in children's school routines, the hypothesized mediator of the association between socioeconomic status (SES) and children's reading outcomes. It comprises 32 items divided into three subscales: "family/caregivers - teachers," "family/caregivers - school/administration," and "family/caregivers - students." Only the family/caregivers and students subscale (Items 21 to 32) was used in the present study, because it specifically evaluates caregivers' involvement in children's school routines. The subscale contains 12 dichotomous ("yes" / "no") items that assess practices related to school monitoring, homework support, discussing school performance, identification of difficulties, and emphasizing the importance of schooling. "Yes" responses were scored as 1 and "no" responses as 0, yielding a total score ranging from 0 to 12, with higher scores indicating greater parental involvement in the child's school routine.
- **Participation in extracurricular activities (ECAs)**: Participation in ECAs was assessed through the parent-completed sociodemographic questionnaire. Because musical activities may provide opportunities to develop rhythmic abilities, musical ECAs were examined as a potential moderator of the association between SES and rhythmic skills.

Parents reported the child's weekly participation in structured activities outside regular school hours using a six-point scale ranging from 0 ("does not participate") to 5 ("participates five or more times per week"). Activities included sports, dance, musical instrument lessons, singing, other musical activities, language classes, other artistic activities, and other academic activities. Based on these responses, summary indices were created for musical, academic, sports, and artistic ECAs, as well as an overall participation index. These indicators reflect overall exposure to activity types but do not capture quality, duration, or intensity of participation.

Outcomes

- **Written Sentence Comprehension Subtest - SCSE** (Capovilla & Seabra, 2013): The SCSE assesses silent reading comprehension in children. It consists of 40 short sentences, each accompanied by five pictures. For each item, children select the picture that best represents the sentence. The total score range was 0 to 40, with high score indicating a better performance. The instrument was developed based on cognitive models of text comprehension and has shown adequate evidence of validity and internal consistency (Dias et al., 2014). Total raw scores were used in the present study. Tests with more than 10% unanswered items were treated as missing.
- **Word and Pseudoword Reading Competence Test - TCLPP** (Seabra & Capovilla, 2010): It assesses children's silent reading of words and pseudowords. It includes 70 stimuli organized into seven sets of 10 items, comprising regular and irregular words, semantically incongruent words, and pseudowords with different types of orthographic and phonological alterations. For each item, children judge whether the word or pseudoword correctly matches the corresponding image. Thus, the measure reflects performance in word- and pseudoword-level reading judgments rather than a pure measure of decoding accuracy. The TCLPP has evidence of validity and reliability in Brazilian samples, with normative data available for children from 1st to 5th grade in public and private schools (Dias et al., 2014). Total raw scores were used in the present study. Tests with more than 10% unanswered items were treated as missing.
- **Rhythm perception**: Rhythm perception was assessed using an adaptation of the *Perception of Musical Meter* task originally developed by Huss et al. (2011), using the shortened 18-trial version described by Flaugnacco et al. (2014). The task comprised nine "same" and nine "different" trials, in which children listened to two successive rhythmic sequences and judged whether they were identical or different. In the present study, the administration procedure was adapted for collective assessment in small groups of up to 10 children. Rather than providing an individual verbal or computerized response, children recorded each judgment on a printed response sheet by marking whether the two sequences were "same" or "different". The response sheet included written labels and visual musical-note cues to facilitate task comprehension. Two practice trials were administered before the 18 experimental trials. The total number of correct responses was used as the rhythm perception score (range: 0–18).

- **Rhythm reproduction**: This motor task assessed children's ability to reproduce rhythmic patterns. Participants listened through headphones to four rhythmic sequences, each composed of 3 to 8 tones lasting 65 ms, and were instructed to reproduce each sequence as accurately as possible by tapping a pencil on a table with their dominant hand. The task followed the complex rhythm reproduction paradigm described by Hidalgo et al. (2021). Responses were recorded with a microphone positioned near the participant's hand. Before testing, children completed a brief practice session to ensure understanding of the instructions. Audio presentation and recording were performed using Audacity (Version 3.6.1; Audacity Team, 2024). Tap onsets were extracted from the recordings using a custom Python script and compared with the original rhythmic patterns. The task yielded one correlation score for each of the four rhythmic sequences, reflecting the temporal similarity between the participant's response and the target pattern. The mean of these four scores was used in the present study.

Procedure

The study was first presented to teachers and to the parents or legal guardians of participating children. During these meetings, the study objectives and procedures were explained, informed consent was obtained, and the parent questionnaires were distributed.

Most child assessments were administered collectively during regular class periods, with support from the classroom teachers. The WASI (Yates et al., 2006), used as an inclusion criterion, and the rhythm reproduction task were administered individually. Group assessments were divided into several sessions to reduce fatigue. Reading measures were administered in separate sessions lasting approximately 50 minutes each, whereas the rhythm perception task lasted approximately 20 minutes and was administered to groups of 8 to 10 children. Individual assessments lasted approximately 40 minutes in total.

Assessments were conducted across two school years, from March 2024 to November 2025. Phase 1 (March–June 2024) included the collection of sociodemographic information and extracurricular activity data. Phase 2 (October–November 2024) consisted of the parental involvement questionnaire. Phase 3 (October–November 2025) included the administration of the reading and rhythm assessments. The assessment team included psychologists, educators, and undergraduate and graduate students in related fields, all of whom were trained prior to data collection.

Table 2

Description of the Procedure According to Data Collection Phase, Respondent, and Extracted Variables

Phase	Instrument	Respondent	Variables
Phase 1 (predictors)	Sociodemographic questionnaire	Parent/ legal guardian	Composite SES index (maternal education and family income); family income; household composition; current and past participation in extracurricular activities.
Phase 2 (mediators)	Checklist of shared routines and family-school involvement	Parent/ legal guardian	Parental involvement in the school routine (total score).
Phase 3 (outcomes)	Written Sentence Comprehension Subtest - SCSE	Child	Reading comprehension (raw score).
	Word and Pseudoword Reading Competence Test - TCLPP		Word and pseudoword reading competence (raw score).
	Rhythm perception		Rhythm perception (number of correct responses).
	Rhythm reproduction		Rhythm reproduction (z score - mean correlation across the four responses).

Data Analysis

Rhythm Reproduction Performance

The rhythm reproduction task comprised four distinct rhythmic stimuli, each repeated eight times. Following the general procedure used by Hidalgo et al. (2021), initial repetitions were treated as a learning/practice phase and excluded from the analysis. Whereas Hidalgo et al. excluded the first three repetitions, in the present study the first two repetitions of each stimulus were excluded, and the remaining six were analyzed. The purpose of the audio analysis was to quantify the degree of temporal correspondence between the presented patterns (stimuli) and the responses produced by participants.

Recordings were screened for technical and procedural validity, and unusable recordings due to recording, equipment, file, or processing errors were excluded. Participants with fewer than two valid responses were assigned a missing aggregate score. Of the 164 participants with recorded data, 15 met this criterion, resulting in aggregate scores being available for 149 participants.

Audio files were processed automatically using custom Python scripts (see Online Resource 1) to ensure reproducibility and standardization, then visually verified. First, rhythmic events (taps) were extracted from each recording through automatic peak detection.

After extraction, the taps were represented as discrete time series, in which the presence of an event was coded as one and its absence as zero. This representation allowed direct comparison between the rhythmic patterns of the stimuli and the responses produced by participants.

Several preprocessing adjustments were applied, as detailed in Online Resource 1, to standardize the comparison between stimulus and response signals. Rhythm reproduction accuracy was then quantified using normalized cross-correlation. For each stimulus, the rhythm reproduction score corresponded to the maximum value of the cross-correlation function, representing the highest degree of temporal similarity between the participant's response and the target rhythmic pattern. This approach captures the overall temporal structure of the reproduced rhythm while accommodating small variations in motor timing. This objective scoring approach was based on Hidalgo et al. (2021). In the original study, the correlation-based measure was additionally compared with subjective ratings provided by three expert judges as a validation procedure. In the present study, rhythm reproduction was quantified exclusively using the objective correlation-based procedure; no subjective judge ratings were obtained.

For inferential analyses, the rhythm reproduction score was the mean of the results from the four stimuli. Before aggregation, internal consistency among the indicators was evaluated. The coefficients obtained indicated adequate levels of reliability ($\alpha = .81$; $\omega = .82$), suggesting sufficient common variance among the stimuli to compose an aggregate measure of the construct. Correlation coefficients were first transformed using Fisher’s z, after which the mean across the four stimuli was calculated.

Statistical Analysis

Statistical analyses were organized in stages according to the proposed objectives and hypotheses. First, descriptive analyses were conducted to characterize the sample in terms of sociodemographic, environmental, rhythmic, and reading variables. Data normality was assessed using the Shapiro-Wilk test, and the choice of subsequent tests took the distribution of variables into account. To examine grade differences in reading outcomes, rhythmic skills, and parental involvement, Kruskal-Wallis tests were used. When significant, Dwass-Steel-Critchlow-Fligner post hoc comparisons were conducted.

To test the hypothesis that SES is directly associated with reading performance and rhythmic skills, Spearman correlation analyses were conducted. Associations between environmental variables and reading and rhythm outcomes were also tested.

To test the hypothesis that the effect of SES on reading skills occurs, at least in part, indirectly through parental involvement, regression-based mediation analyses were conducted. Following a path-modelling approach within a structural equation modelling framework, the total effect, the indirect effect via the mediator, and the remaining direct effect of the predictor variable on the outcome were estimated for each model. In the models tested, SES was specified as the predictor variable (X), parental involvement as the mediator (M), and reading outcomes (Y) were analyzed separately, including reading comprehension and word and pseudoword reading competence. School grade was included as a covariate in all models, to account for developmental differences in reading and rhythmic skills across

grades. The temporal and logical ordering of the models considered the predictor as the antecedent variable, the mediator as the potential mechanism (obtained in Phase 2 of data collection), and reading performance as the outcome (Phase 3).

Mediation models were estimated in Stata BE 17 (StataCorp LLC, 2021) using the *sem* command with maximum likelihood estimation. First, the coefficients for individual model paths were examined: (a) the association between SES and the mediator; (b) the association between the mediator and the outcome, controlling for the predictor; and (c) the direct association between SES and the outcome after inclusion of the mediator. Total effects were estimated in reduced models excluding the mediator but using the same complete-case sample as the corresponding mediation model. Direct effects were obtained from the full mediation models, and indirect effects were calculated as the product of the relevant paths using nlcom. Bias-corrected bootstrap confidence intervals with 10,000 replications were used for inference on the indirect effects. Standardized coefficients (β) were used in the structural diagrams of the models (Lei & Wu, 2007). Cases with missing data on any variable included in each model were automatically excluded by the procedure, resulting in specific sample sizes for each analysis.

To test whether participation in musical ECAs moderated the relation between SES and rhythm outcomes, linear regression models with interaction terms were used. Unlike the mediation models, which test explanatory mechanisms, moderation analyses assess whether the strength or direction of the associations varies by levels of a third variable. Separate moderation models were estimated for rhythm reproduction and rhythm perception, with SES as the predictor and musical ECAs as the moderator. Syntax for the mediation and moderation analyses conducted in Stata (StataCorp LLC, 2021) is provided in Online Resource 2.

Results

Table 3 presents descriptive statistics for reading outcomes, rhythmic skills, and parental involvement, both for the total sample and by school grade. Kruskal-Wallis tests revealed significant grade differences in reading comprehension ($\chi^2(2) = 25.36$, $p < .001$, $\varepsilon^2 = .14$), word and pseudoword reading competence ($\chi^2(2) = 20.80$, $p < .001$, $\varepsilon^2 = .11$), rhythm perception ($\chi^2(2) = 7.43$, $p = .024$, $\varepsilon^2 = .05$), and rhythm reproduction ($\chi^2(2) = 7.12$, $p = .028$, $\varepsilon^2 = .05$). No significant grade differences were observed for parental involvement ($\chi^2(2) = 0.02$, $p = .988$, $\varepsilon^2 = .00$).

Post hoc Dwass-Steel-Critchlow-Fligner comparisons indicated that 1st-grade children performed significantly lower than 2nd and 3rd grade children in reading comprehension and word and pseudoword reading competence. For rhythm perception, 3rd-grade children outperformed both 1st and 2nd grade children, whereas for rhythm reproduction, only the difference between 1st and 3rd grade was significant.

Table 3

Descriptive Statistics for Reading Outcomes, Rhythmic Skills, and Parental Involvement

	Total	**1st grade**	**2nd grade**	**3rd grade**
Word and pseudoword reading competence				
N	188	63	57	68
Minimum	12	12	45	43
Maximum	70	69	70	70
Mean (SD)	60.22 (8.74)	56.03 (11.01)	61.65 (6.44)	62.91 (6.41)
Reading comprehension				
N	184	63	55	66
Minimum	4	4	6	8
Maximum	40	40	40	40
Mean (SD)	34.02 (8.90)	30.25 (11.14)	34.44 (8.22)	37.27 (4.91)
Rhythm perception				
N	165	57	54	54
Minimum	0	0	5	7
Maximum	17	17	17	17
Mean (SD)	10.75 (2.86)	10.23 (2.98)	10.39 (2.87)	11.65 (2.53)
Rhythm reproduction				
N	149	48	49	52
Minimum	0.53	0.54	0.58	0.53
Maximum	0.98	0.97	0.98	0.97
Mean (SD)	0.81 (0.10)	0.78 (0.11)	0.82 (0.1)	0.85 (0.09)
Parental involvement				
N	114	52	26	36
Minimum	6	6	7	8
Maximum	12	12	12	12
Mean (SD)	10.79 (1.29)	10.81 (1.33)	10.69 (1.46)	10.83 (1.13)

Note. For descriptive purposes, rhythm reproduction scores are presented in the original correlation metric.

Association Between SES, Rhythmic Skills, and Reading Skills

To investigate associations among environmental variables, rhythmic skills, and reading outcomes, Spearman correlation analyses were conducted (Table 4). School grade was positively associated with all four study outcomes. The composite SES index was positively associated with reading comprehension (ρ = .19, *p* = .036), but was not significantly associated with word and pseudoword reading performance or either rhythmic skill.

Regarding individual socioeconomic and environmental indicators, family income was positively associated with both reading comprehension and word and pseudoword reading performance (ρ = .26 for both). Parental involvement was also positively associated with reading comprehension (ρ = .23) and word and pseudoword reading performance (ρ = .21). Paternal education was positively associated with rhythm perception (ρ = .22), whereas maternal education and household composition were not significantly associated with the study outcomes.

Regarding extracurricular activities, academic ECAs were negatively associated with reading comprehension (ρ = − .27) and word and pseudoword reading performance (ρ = − .32), while artistic ECAs were negatively associated with reading comprehension (ρ = − .33). Total, musical, and sport ECAs were not significantly associated with reading or rhythmic outcomes.

Finally, among the associations between rhythmic skills and reading outcomes, rhythm reproduction was positively associated with word- and pseudoword reading performance (ρ = .30, *p* < .001). The remaining rhythm-reading correlations were not statistically significant.

Table 4

Spearman Correlations Between Environmental Variables, Rhythmic Skills, and Reading Outcomes

Panel A. *Environmental Variables, Rhythm and Reading Associations*

Variable	Reading comprehension	Word and pseudoword reading	Rhythm perception	Rhythm reproduction
Grade	**.37*** **	**.32*** **	**.18***	**.21****
Composite SES index	**.19***	.13	.01	− .12
Maternal education	.05	.02	.06	− .06
Paternal education	.13	.07	**.22***	.03
Family income	**.26****	**.26****	− .03	− .14
Household composition	− .07	− .12	− .04	− .09
Parental involvement	**.23***	**.21***	.02	.17
Total ECAs	− .17	− .10	.01	.01
Musical ECAs	− .02	− .01	.04	.08
Artistic ECAs	− .33	− .13	− .11	− .01
Academic ECAs	**− .27****	**−.32*** **	− .15	− .10
Sport ECAs	− .14	− .06	.04	− .07

Panel B. *Rhythm-Reading Associations*

Rhythmic skill	Reading comprehension	Word- and Pseudoword reading
Rhythm perception	.13	.15
Rhythm reproduction	.15	**.30*** **

Note. Values are Spearman's ρ coefficients. SES = socioeconomic status; ECAs = extracurricular activities. Rhythm reproduction corresponds to the aggregate Fisher-*z*-transformed score used in inferential analyses. **p < .05, **p < .01, ***p < .001.*

Indirect Relation Between SES and Reading Skills

To test whether parental involvement mediated the relation between SES and reading outcomes, mediation models were tested using structural equation modeling with maximum likelihood estimation (Figs. 2 and 3).

Note

Values shown on the arrows correspond to standardized coefficients (β).

For reading comprehension (n = 87), the total effect of SES was significant (b = 3.76, SE = 0.99, z = 3.79, p < .001, 95% CI [1.82, 5.71]). After inclusion of the mediator, the direct effect remained significant (b = 3.63, SE = 0.97, z = 3.73, p < .001, 95% CI [1.72, 5.53]), but the indirect effect via parental involvement was not (b = 0.16, SE = 0.26, z = 0.62, p = .535, 95% CI [− 0.10, 1.04]).

Note

Values shown on the arrows correspond to standardized coefficients (β).

For word and pseudoword reading competence (n = 103), no total (b = − 0.96, 95% CI [− 5.41, 3.50], p = .674), direct (b = − 1.11, 95% CI [− 5.66, 3.43], p = .631), or indirect effects (b = 0.16, 95% CI [− 0.81, 1.96], p = .802) were significant. School grade was included as a covariate in all models.

Moderation of Participation in ECAs in the Relation Between SES and Rhythmic Skills

To investigate whether musical extracurricular activities moderated the relation between SES and rhythmic skills, a linear regression model with interaction terms was used. For rhythm reproduction (n = 94) no significant interaction effect (b = 0.015, SE = 0.041, t = 0.36, p = .719, 95% CI [-0.066, 0.095]) or main effects of SES (b = -0.053, p = .258) or musical ECAs (b = 0.007, p = .811) were observed (R^2 = .015).

Similarly, for rhythm perception (n = 106), no significant interaction effects (b = -0.39, 95% CI [-0.99, 0.21], p = .200) or main effects (b = 0.41, 95% CI [-0.27, 1.08], p = .230), or musical extracurricular activities (b = -0.07, 95% CI [-0.48, 0.34], p = .720) were observed (R^2 = .023).

Discussion

The present study investigated associations between socioeconomic factors, parental involvement, extracurricular activities (ECAs), reading performance and rhythmic skills in Brazilian primary school children from low-SES backgrounds. Results showed that family income and parental involvement were positively associated with reading outcomes, especially comprehension, whereas rhythmic skills were not associated with SES or participation in musical ECAs. In addition, rhythmic reproduction, but not rhythm perception, was positively associated with word and pseudoword reading competence. Together these findings suggest that reading performance and rhythmic abilities may be differentially associated with environmental factors and support further investigation of rhythm reproduction as a correlate of early reading development.

Environmental Predictors of Reading

The positive association between family income and reading outcomes aligns with the family investment model (Conger & Donnellan, 2007), which posits that higher-SES families are better able to provide educational materials, learning opportunities, and supportive home environments that promote children's cognitive development. Family income was also associated with parental involvement, consistent with evidence that socioeconomic advantages enable greater investment in children's education (Carneiro et al., 2013; Piccolo et al., 2016).

Contrary to our hypotheses, parental involvement did not mediate the association between SES and reading performance. Although both SES and parental involvement were independently associated with reading comprehension, the indirect effect through parental involvement was not statistically significant.

One possible explanation is the restricted SES range in the present sample, where most families belonged to a relatively similar low-income background. Limited variability may have reduced the ability to detect indirect effects.

Another possibility concerns the measurement of parental involvement. The questionnaire primarily assessed caregivers' monitoring of school routines, homework, and communication with the school, rather than broader home literacy practices such as shared reading or literacy-related interactions. Previous research suggests that these literacy-specific activities may be more strongly associated with children's reading development (Inoue et al., 2018). Furthermore, because parental involvement was measured through caregiver self-report and scores showed relatively little variability, social desirability or ceiling effects may have attenuated the observed associations.

Taken together, these findings suggest that SES and parental involvement contribute to children's reading performance through partially independent pathways. Other mechanisms not examined in the present study, such as phonological awareness, vocabulary, executive functions, school quality, or characteristics of the home literacy environment, may account for a larger proportion of the association between socioeconomic disadvantage and reading outcomes.

Rhythmic Skills and Socioeconomic Factors

Unlike reading outcomes, rhythm skills were not associated with family income, parental education, or participation in extracurricular activities. Rather than indicating that rhythmic abilities are independent of socioeconomic influences, these findings suggest that, within the socioeconomic range represented in this sample, rhythmic skills showed weaker associations with the measured environmental variables than reading outcomes. This may reflect that rhythm relies on cognitive processes like auditory-motor synchronization and sequential processing (Kim et al., 2023; Pranjić et al., 2024; Tierney & Kraus, 2014), which may be less tied to socioeconomic resources than other skills.

Restricted SES variability is again likely to have contributed to these findings. Because most participating families belonged to similar socioeconomic backgrounds, the study may have lacked sufficient variability to detect subtle associations between SES and rhythmic performance. Consequently, these results

should not be interpreted as evidence that socioeconomic factors do not influence rhythmic development, but rather that such associations were not detectable in the present sample.

Participation in extracurricular activities likewise showed limited associations with the study outcomes. Contrary to expectations, musical extracurricular activities neither predicted rhythmic performance nor moderated the association between SES and rhythm. One possible explanation is that the measure captured only participation frequency, without considering important characteristics such as duration, intensity, instructional quality, or cumulative years of practice, all of which may be more relevant for developing rhythmic abilities (Theroux et al., 2025).

Interestingly, academic extracurricular activities showed weak negative correlations with reading outcomes. Rather than suggesting that these activities impair reading development, this finding more likely reflects reverse causality. Children experiencing academic difficulties may be more likely to receive tutoring or remedial educational support, resulting in a negative association between participation in academic ECAs and reading performance.

Rhythm and Reading

The most consistent finding involving rhythmic skills was the positive association between rhythm reproduction and word and pseudoword reading competence. Although modest in magnitude, this association agrees with previous studies reporting links between rhythmic processing and reading development (Flaugnacco et al., 2014; Ozernov-Palchik et al., 2018; Tierney et al., 2021) .

The absence of a similar association for rhythm perception may reflect differences in the cognitive demands of the two tasks. Rhythm reproduction likely relies not only on perceiving temporal patterns but also on maintaining those patterns in working memory, organizing sequential information, and translating auditory representations into coordinated motor responses. These processes overlap with several cognitive abilities thought to contribute to successful word reading, including sequential processing, phonological ordering, grapheme-phoneme mapping, and auditory-motor integration (Degé & Schwarzer, 2011; Hidalgo et al., 2021; Sousa et al., 2022). Consequently, children who reproduce rhythmic sequences more accurately may also demonstrate greater efficiency in word decoding.

By contrast, reading comprehension depends on additional higher-level linguistic processes, including vocabulary, syntactic knowledge, inference generation, and comprehension monitoring, which may reduce the relative contribution of rhythmic processing. This interpretation is consistent with the present findings, in which rhythm reproduction was associated specifically with word and pseudoword reading rather than comprehension.

Limitations

This study has several limitations that should be considered when interpreting the findings. First, sociodemographic characteristics, parental involvement, and participation in ECAs were assessed through parent report and may therefore be affected by reporting bias. Second, missing data reduced the

effective sample size, particularly in the mediation and moderation analyses, which may have limited statistical power. Third, although the prospective three-wave design established temporal ordering between the predictor, mediator, and outcomes, the study was observational and therefore does not allow causal conclusions regarding the associations examined. In addition, the ECA measure captured frequency of participation but not duration, intensity, instructional quality, or cumulative experience, which may have limited its ability to detect associations with rhythmic skills. Finally, participants were recruited from a single public school serving a relatively socioeconomically homogeneous population, which limits the generalizability of the findings and may have reduced the variability needed to detect socioeconomic associations with rhythmic skills.

Implications and Future Directions

An important implication of the present findings is that rhythm reproduction may represent a promising avenue for future research on reading development in socioeconomically vulnerable populations. Because rhythmic skills showed weaker associations with the socioeconomic indicators measured in this sample than reading outcomes, they may represent a relatively accessible target for intervention across diverse socioeconomic contexts. However, the present findings are correlational and should not be interpreted as evidence that improving rhythmic skills causes improvements in reading.

Future longitudinal and intervention studies should examine whether rhythm-based training can produce meaningful gains in word and pseudoword reading competence and investigate the cognitive mechanisms underlying this relationship. Additional work should also explore broader measures of the home literacy environment, school quality, and cognitive predictors of reading, while examining more socioeconomically diverse samples to determine whether the present findings generalize beyond the specific context studied here.

Declarations

Author Contribution

A.B.S.H. wrote the manuscript, conducted the data analysis, and participated in data collection. G.Z. participated in data collection. M.D. contributed to the data analysis. D.S. reviewed the manuscript and the data analysis. A.G.S. coordinated the broader project in which the study was conducted and reviewed the manuscript. N.B. supervised the study and reviewed the manuscript. All authors reviewed and approved the final manuscript.

Data Availability

The datasets generated and analyzed during the current study are not publicly available but are available from the corresponding author upon reasonable request.

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Figures

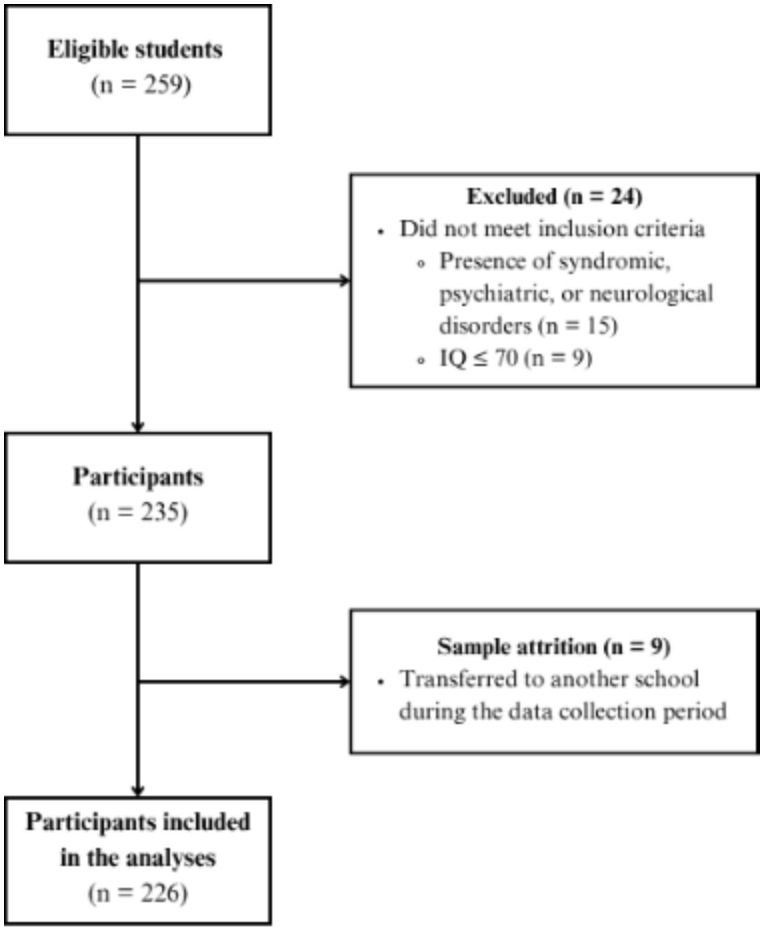

Figure 1

Flowchart of Participant Inclusion in the Study

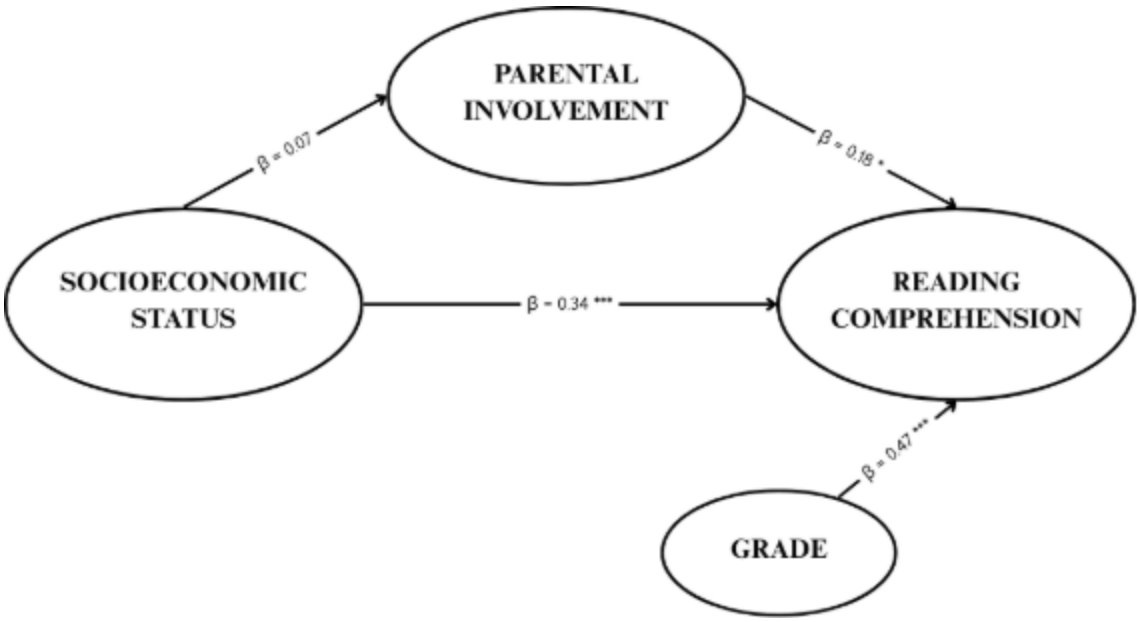

Figure 2

Mediation Model Among SES, Parental Involvement, and Reading Comprehension

Note. Values shown on the arrows correspond to standardized coefficients (β).

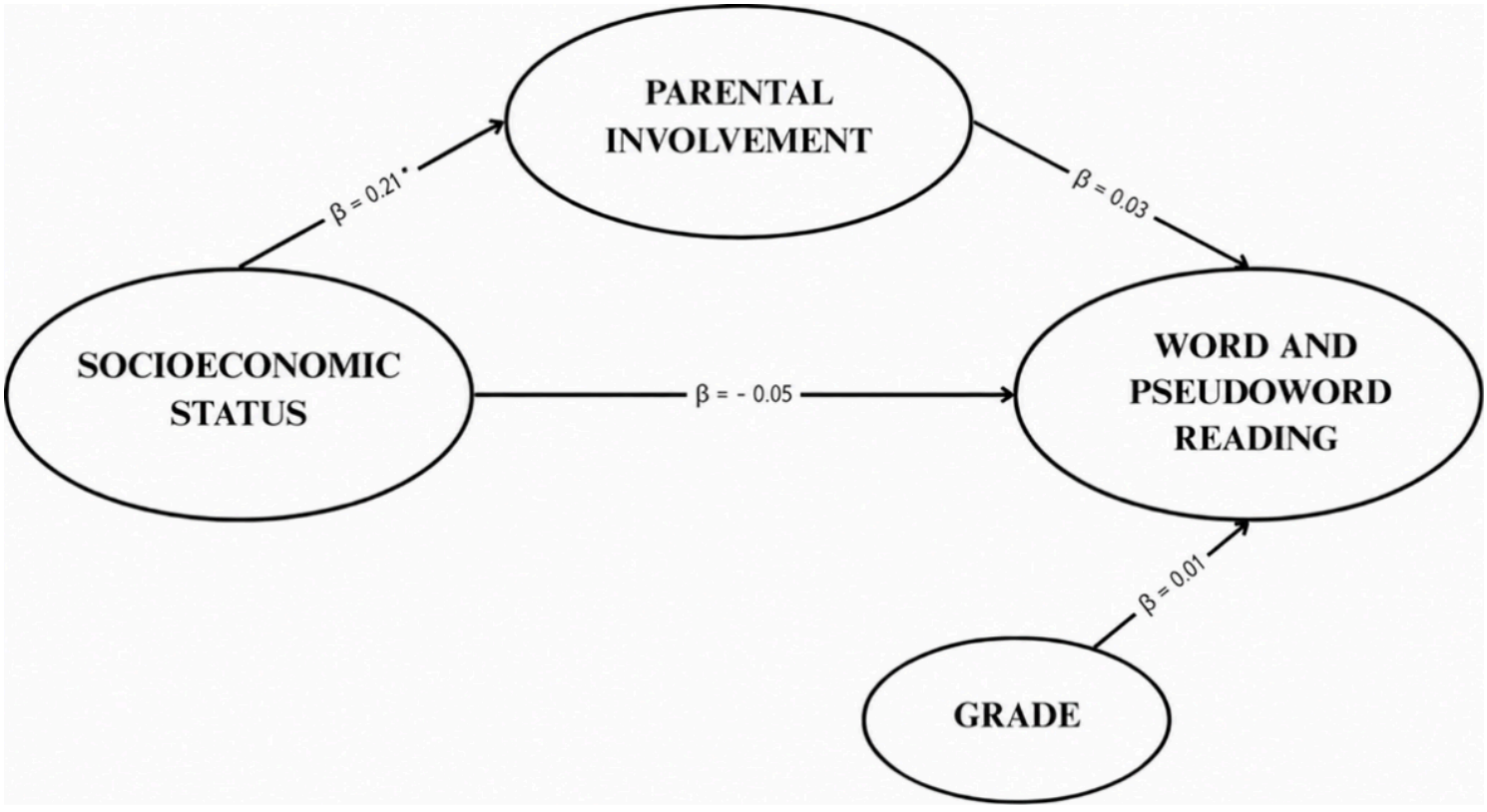

Figure 3

Mediation Model Among SES, Parental Involvement, and Word and Pseudoword Reading Competence

Note. Values shown on the arrows correspond to standardized coefficients (β).

Supplementary Files

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- ESM2.pdf
- ESM1.pdf