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RECEIVED: January 27, 2026

ACCEPTED: April 14, 2026

PUBLISHED: May 27, 2026

CITATION APA STYLE 7:

Nuraini, N., Lacombe, L., & Hamilton, R. (2026).  
Language Processing Speed as a Strong  
Predictor of Academic Achievement in  
Elementary School Students. *Journal of  
Foundational Learning and Child Development*,  
2(02), 90-96.  
<https://doi.org/10.53905/ChildDev.v2i02.13>

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# Language Processing Speed as a Strong Predictor of Academic Achievement in Elementary School Students

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## ABSTRACT

**Purpose of the study:** This study aims to examine the relationship between language processing speed and academic achievement across multiple domains in elementary school students. It also investigates the differential predictive values of simple versus complex processing speed components and developmental patterns across grade levels.

**Materials and methods:** A quantitative cross-sectional design was employed involving 485 elementary students from grades 1 to 5, aged 6.2 to 11.8 years. Participants underwent assessments of simple and complex processing speed, language processing speed (e.g., Rapid Automatized Naming), and academic achievement using standardized tests in reading, mathematics, and language arts. Data were analyzed using correlation, hierarchical regression, and structural equation modeling to determine the predictive contributions of processing speed components to academic outcomes.

**Results:** Findings indicated significant moderate to strong positive correlations ( $r = .34$  to  $.67$ ) between language processing speed and academic performance. Complex processing speed was more strongly associated with higher-order academic skills such as reading comprehension and mathematical problem-solving, while simple processing speed related more to basic academic skills. Reading fluency emerged as the strongest predictor of academic achievement, with specific processing speed measures explaining additional variance beyond age, grade, and general cognitive ability.

**Conclusions:** Language processing speed is a critical predictor of academic achievement in elementary students, with complex processing speed playing a pivotal role in higher-order cognitive tasks. Early identification and intervention focusing on processing speed components can enhance learning outcomes. Future longitudinal research is warranted to explore causal pathways and effective interventions for students with processing speed deficits.

## Keywords

Language processing speed; academic achievement; elementary education; processing speed components; reading fluency.

## INTRODUCTION

### Contextual Framework of the Research

Processing speed represents a fundamental cognitive ability that underlies efficient information processing and academic performance in educational settings. Within the context of elementary education, language processing speed encompasses the rapid and accurate processing of linguistic information, including phonological awareness, word recognition, semantic retrieval, and syntactic processing (Forchelli et al., 2021; Gerst et al., 2021)[1]. This cognitive capacity becomes increasingly critical as students progress through elementary grades, where academic demands require rapid integration of multiple cognitive processes for successful learning outcomes (Decker et al., 2016; Shea & Ceprano, 2017).

The developmental trajectory of processing speed during elementary school years follows a characteristic pattern of nonlinear growth, with the most intensive improvements occurring between grades 1 and 2, followed by continued but more gradual development through grade 4 (Adolph et al., 2008; Gordon et al., 2018)[2]. This developmental pattern coincides with critical periods of academic skill acquisition, particularly in reading and mathematical competencies that form the foundation for subsequent educational success.

Elementary school students face increasing demands for rapid information processing across multiple academic domains. Reading fluency requires efficient integration of phonological processing, orthographic recognition, and semantic access, while mathematical problem-solving demands quick retrieval of arithmetic facts and procedural knowledge (Catalano et al., 2025). Students with slower processing speeds often struggle to meet these temporal demands, resulting in compromised academic performance despite adequate underlying cognitive abilities (Kulman, 2025; Subhan & Suyanto, 2023).

### Critical Examination of Existing Literature

Recent research has established processing speed as a multifaceted construct that can be differentiated into simple and complex components, each contributing uniquely to academic outcomes. A study involving children showed that a model of complexity with two factors, differentiating between simple and complex processing speed, was a better fit compared to models that

considered processing speed as a single factor (Chiaravalloti et al., 2003; Peterson et al., 2016). This research revealed that both types of processing speed predicted reading fluency, while complex processing speed specifically predicted single-word reading and comprehension abilities. Further investigation has shown that processing speed deficits can impact academic performance across multiple domains, leading to slower completion times and difficulties with multi-step cognitive operations (Elleseff, 2024; Forchelli et al., 2021). Such deficits can be particularly pronounced in timed academic tasks, where students with slower processing speeds may struggle to keep pace with their peers (Dexter & Ossmy, 2023). In addition, processing speed deficits can also impact working memory, which is essential for retaining and manipulating information during complex cognitive tasks.

The differential impact of general versus specific processing speed on academic achievement has been a subject of considerable investigation. Research with junior high school students demonstrated that specific processing speed measures, including reading fluency and arithmetic fluency, made significant unique contributions to mathematical achievement, while general processing speed measures failed to predict academic outcomes (Cassidy et al., 2016; Georgiou et al., 2021). These findings suggest that domain-specific processing efficiency may be more critical for academic success than broad processing speed abilities.

Studies examining the academic implications of processing speed deficits have identified widespread impacts across multiple educational domains. Students with slower processing speeds demonstrate difficulties with reading fluency and comprehension, often exhibiting slow and choppy oral reading patterns that compromise text comprehension due to excessive cognitive resources devoted to decoding processes (Bai et al., 2020; Stevens et al., 2016)[4]. Similarly, written expression tasks become particularly challenging, as these students struggle to integrate motor skills, language retrieval, and organizational demands within typical time constraints (Schurer et al., 2020).

The social and classroom participation consequences of processing speed deficits extend beyond purely academic concerns. Students with slower processing speeds often experience difficulties with group work, struggle to follow fast-paced conversations, and may appear disorganized when sharing information with peers (Anderson et al., 2013; Thorsen et al., 2018). These challenges can lead to social isolation and reduced participation in classroom activities, creating secondary effects on motivation and academic engagement.

### Identification of Research Gaps

Despite substantial research demonstrating relationships between processing speed and academic performance, several critical gaps remain in our understanding of these connections within elementary school populations. First, much of the existing research has focused on older students or has examined processing speed as a unitary construct, failing to adequately differentiate between the various components that may differentially predict academic outcomes in younger learners.

Second, there is limited research specifically examining language processing speed as distinct from other processing speed components in elementary school settings. While studies have demonstrated the importance of reading fluency and phonological processing speed, comprehensive investigation of broader language processing speed components and their relationships to academic achievement remains incomplete.

Third, existing research has primarily focused on reading and mathematical outcomes, with limited attention to the broader spectrum of academic skills that characterize elementary education. Understanding how language processing speed relates to diverse learning outcomes, including written expression, oral language skills, and content area learning, represents an important area for investigation.

### Rationale for the Research

The investigation of language processing speed and its relationship to elementary school learning performance addresses several critical educational and scientific needs. From an educational perspective, understanding these relationships can inform early identification procedures for students at risk for academic difficulties, enabling implementation of targeted interventions during critical developmental periods (Morgan et al., 2009; Shaul & Nevo, 2015).

The research also addresses theoretical questions about the nature of processing speed and its role in academic skill development. By examining both general and specific processing speed components, this study contributes to ongoing debates about the structure of cognitive abilities and their differential contributions to learning outcomes.

Practically, this research provides essential information for educators and educational psychologists working with elementary school students. Understanding how processing speed deficits manifest across different academic domains can guide the development of appropriate classroom accommodations and instructional modifications to support student success (Gordon et al., 2018; Goyibova et al., 2025).

### Objectives

The primary objectives of this study were to: (1) examine the relationship between language processing speed and academic achievement across multiple domains in elementary school students; (2) investigate the differential predictive value of simple versus complex processing speed components for learning outcomes; (3) analyze developmental patterns in processing speed and academic performance relationships across elementary grade levels; (4) identify specific processing speed components that most strongly predict academic success in reading, mathematics, and language arts; and (5) examine the implications of processing speed deficits for classroom learning and social participation

## METHODOLOGY

### Study Participants

The study included 485 elementary school students enrolled in grades 1 through 5 in urban public elementary schools. Participants ranged in age from 6.2 to 11.8 years ( $M = 8.7$  years,  $SD = 1.4$  years), with approximately equal representation across grade levels and gender distribution (52% female, 48% male). Students were recruited from six elementary schools representing

diverse socioeconomic backgrounds to ensure generalizability of findings.

Inclusion criteria required students to have English as their primary language of instruction, absence of diagnosed intellectual disabilities, and adequate hearing and vision for test participation. Students with identified learning disabilities were included in the sample to capture the full range of processing speed abilities present in typical elementary school populations. Parental consent and student assent were obtained for all participants prior to data collection.

## Study Organization

This study employed a quantitative cross-sectional design to examine relationships between processing speed measures and academic achievement indicators. Data collection occurred during the spring semester to ensure students had adequate exposure to grade-level curriculum content. Testing was conducted in quiet school environments by trained research assistants following standardized administration procedures.

The research design incorporated multiple measures of processing speed, including both general cognitive processing tasks and specific academic processing measures. Academic achievement was assessed using standardized tests and curriculum-based measures to provide comprehensive evaluation of learning performance across key academic domains.

Table 1. Test and Measurement Procedures

Assessment Category	Measurement Tools/Tasks
Processing Speed Assessment	- Simple Processing Speed: Symbol coding tasks, digit-symbol substitution, visual matching exercises (rapid, straightforward cognitive operations).- Complex Processing Speed: Tasks requiring higher-order cognitive operations, such as working memory updating, cognitive flexibility, and dual-task paradigms.
Language Processing Speed Measures	- Rapid Automatized Naming (RAN): Tasks for letters, numbers, and objects.- Phonological Processing Speed: Phoneme deletion and blending tasks under timed conditions.- Reading Fluency: Word reading fluency, passage reading fluency (assessing speed and accuracy of linguistic processing).
Academic Achievement Assessment	- Reading Achievement: Word reading accuracy, reading fluency, reading comprehension.- Mathematical Achievement: Computation fluency, mathematical problem-solving, arithmetic fact retrieval.- Language Arts Achievement: Spelling, written expression, oral language comprehension.
Supplementary Measures	- Working Memory: Measures assessing the ability to hold and manipulate information.- Attention: Tasks to evaluate sustained and selective attention.- Executive Function: Measures of cognitive control and planning.- Demographic Information & Teacher Ratings: For context and interpretation of results.

## Statistical Analysis

Quantitative data were analyzed using SPSS version 28.0. Descriptive statistics were calculated for all variables, and correlation analyses examined relationships between processing speed measures and academic achievement indicators. Hierarchical regression analyses were conducted to determine the unique contribution of different processing speed components to academic outcomes while controlling for age, grade level, and general cognitive ability.

Structural equation modeling was employed to test alternative models of processing speed structure and examine pathways from processing speed components to academic achievement. Multiple group analyses investigated developmental differences across grade levels, and mediation analyses examined potential mechanisms through which processing speed influences academic performance.

## RESULTS

### Articulating Research Outcomes in an Objective Manner

The analysis revealed significant relationships between language processing speed and elementary school learning performance across all measured academic domains. Correlation analyses demonstrated moderate to strong positive correlations between processing speed measures and academic achievement, with correlation coefficients ranging from  $r = .34$  to  $r = .67$  for different processing speed-academic achievement pairs.

Hierarchical regression analyses indicated that specific processing speed measures accounted for significant variance in academic achievement beyond that explained by age, grade level, and general cognitive ability. Reading fluency measures emerged as the strongest predictors of reading achievement ( $\beta = .52$ ,  $p < .001$ ), while arithmetic fluency significantly predicted mathematical performance ( $\beta = .48$ ,  $p < .001$ ).

The two-factor model distinguishing simple and complex processing speed demonstrated superior fit to the data compared to unitary processing speed models ( $\chi^2$  difference = 47.23,  $p < .001$ ). Complex processing speed showed stronger relationships with reading comprehension and mathematical problem-solving, while simple processing speed was more strongly associated with basic academic skills requiring rapid but straightforward cognitive operations.

### Exhibiting Data Through Tables and Graphical Representations

Table 2. Correlations Between Processing Speed Measures and Academic Achievement

Processing Speed Measure	Reading Fluency	Reading Comprehension	Math Computation	Math Problem Solving
Simple Processing Speed	.45**	.32**	.41**	.28**
Complex Processing Speed	.53**	.61**	.47**	.58**
Reading Fluency (RAN)	.67**	.58**	.52**	.49**
Arithmetic Fluency	.48**	.45**	.63**	.56**

Note: \*  $p < .01$

Table 3. Hierarchical Regression Results Predicting Reading Achievement

Step	Variables	R <sup>2</sup>	R <sup>2</sup> Change	F Change	$\beta$
1	Age, Grade Level	.28	.28	47.23**	-
2	General Cognitive Ability	.42	.14	32.15**	.38**
3	Simple Processing Speed	.48	.06	18.92**	.25**

4	Complex Processing Speed	.57	.09	28.47**	.31**
5	Reading Fluency	.69	.12	45.83**	.35**

Note: \*  $p < .01$

## Elucidating the Implications of Statistical Evaluations

The statistical analyses provide several important insights into the relationship between processing speed and academic achievement. The superior predictive power of specific processing speed measures compared to general processing speed indicators suggests that domain-specific cognitive efficiency plays a more critical role in academic success than broad-based processing capabilities. This finding has important implications for both assessment and intervention practices in educational settings.

The differential patterns of prediction observed for simple versus complex processing speed measures indicate that academic tasks requiring higher-order cognitive operations are more dependent on complex processing speed abilities. Reading comprehension and mathematical problem-solving, which require integration of multiple cognitive processes, showed stronger relationships with complex processing speed than with simple processing measures.

The developmental patterns observed across grade levels suggest that the relationship between processing speed and academic achievement strengthens with increasing grade level, likely reflecting the growing cognitive demands of academic curricula. This pattern indicates that processing speed deficits may become increasingly problematic as students progress through elementary school.

## Emphasizing Significant Discoveries

Several significant discoveries emerged from this research that advance our understanding of processing speed and academic achievement relationships. First, the study demonstrated that reading fluency measures, particularly rapid automatized naming tasks, serve as the strongest predictors of academic achievement across multiple domains, not just reading. This finding suggests that efficient linguistic processing underlies success across diverse academic areas.

Second, the research revealed that students with processing speed deficits experience cascading effects across academic domains, with initial difficulties in basic skill fluency leading to problems with higher-order cognitive tasks requiring integration of multiple processes. Students showing slow processing speeds demonstrated particular difficulties with timed academic tasks and multi-step problem-solving activities.

Third, the study identified specific developmental periods when processing speed deficits have the greatest impact on academic achievement. The most critical period appears to be the transition from grade 1 to grade 2, when academic demands increase substantially and processing speed requirements become more pronounced.

## DISCUSSION

### Interpretation of Research Outcomes

The findings of this study provide substantial evidence for the critical role of language processing speed in elementary school academic achievement. The superior predictive power of specific processing speed measures, particularly reading fluency and arithmetic fluency, compared to general processing speed indicators supports theoretical models proposing that domain-specific cognitive efficiency is more important for academic success than broad-based processing capabilities (Gordon et al., 2018; Jacobson et al., 2011).

The two-factor structure of processing speed, distinguishing between simple and complex components, offers important insights into the cognitive mechanisms underlying academic performance. Complex processing speed measures showed stronger relationships with higher-order academic skills such as reading comprehension and mathematical problem-solving, suggesting that these academic domains place greater demands on cognitive integration and executive control processes (Peterson et al., 2016; Wang & Wang, 2024). In contrast, simple processing speed was more strongly associated with basic academic skills requiring rapid but straightforward cognitive operations.

The developmental patterns observed in this study align with previous research demonstrating nonlinear growth in processing speed during elementary school years (Cheng et al., 2021; Gerst et al., 2021). The finding that processing speed shows the most intensive improvement between grades 1 and 2, followed by continued but more gradual development, has important implications for understanding when processing speed deficits may have the greatest impact on academic achievement. This pattern suggests that early identification and intervention for processing speed difficulties may be particularly critical during the primary grades.

### Evaluating in Relation to Antecedent Studies

The current findings are consistent with previous research demonstrating the importance of processing speed for academic achievement while extending these findings to elementary school populations. The study's demonstration that specific processing speed measures outperform general processing measures in predicting academic outcomes aligns with research showing that reading fluency and arithmetic fluency make unique contributions to academic achievement beyond general cognitive abilities (Gallen et al., 2023; Molnár & Kocsis, 2023).

The finding that reading fluency measures serve as strong predictors of achievement across multiple academic domains supports previous research indicating that efficient linguistic processing underlies success in diverse academic areas (Crosson et al., 2024; Wang et al., 2024). This cross-domain predictive power of reading fluency measures suggests that language processing speed represents a fundamental cognitive capacity that supports learning across the curriculum.

However, the current study extends previous research by demonstrating these relationships specifically within elementary

school populations and by examining a broader range of processing speed components. The finding that complex processing speed shows stronger relationships with higher-order academic skills provides new insight into the cognitive mechanisms underlying academic achievement in young learners (Clark et al., 2014; Das & Samantaray, 2023).

The study's identification of developmental periods when processing speed has the greatest impact on academic achievement contributes new knowledge about the timing of processing speed effects. The finding that the relationship between processing speed and academic achievement strengthens with increasing grade level suggests that processing speed deficits may become increasingly problematic as academic demands increase (Cassidy et al., 2016; Clark et al., 2014).

### Elucidating the Ramifications of the Discoveries

The findings of this study have several important ramifications for educational practice and policy. First, the superior predictive power of specific processing speed measures suggests that educational assessments should include domain-specific processing speed evaluations rather than relying solely on general processing speed measures. This recommendation has particular relevance for early identification of students at risk for academic difficulties (Alkan et al., 2025; Meylani, 2024).

Second, the finding that processing speed deficits have cascading effects across academic domains indicates that interventions targeting processing speed improvement may yield benefits across multiple areas of academic performance. This suggests that processing speed training could represent an efficient approach to supporting student academic achievement, particularly for students showing deficits in this area (Okur & Aksoy, 2025; Schulz-Zhecheva et al., 2024).

Third, the developmental patterns observed in this study suggest that early intervention for processing speed difficulties may be particularly important. The optimal time to implement interventions may be during the critical period when processing speed demonstrates the most intensive development (Cepeda et al., 2013; Forchelli et al., 2021).

The study's findings also have implications for classroom instruction and accommodation practices. Students with processing speed deficits may benefit from extended time accommodations, reduced cognitive load in instructional materials, and explicit instruction in strategies for efficient information processing (Braaten et al., 2020; Lovett et al., 2020). Understanding how processing speed deficits manifest across different academic domains can guide teachers in providing appropriate supports and modifications.

### Recognizing the Constraints of the Research

Several limitations of this study should be acknowledged when interpreting the findings. First, the cross-sectional design limits the ability to make causal inferences about the relationship between processing speed and academic achievement. While the study demonstrates significant associations between these constructs, longitudinal research would be needed to establish causal relationships and examine developmental trajectories over time. Second, the study focused primarily on academic achievement outcomes measured through standardized assessments, which may not capture the full range of learning outcomes relevant to elementary education. Future research should examine relationships between processing speed and other important educational outcomes, including social skills, motivation, and classroom participation. Third, the study sample was drawn from urban public elementary schools, which may limit the generalizability of findings to rural or private school populations. Additionally, the requirement that students have English as their primary language of instruction may limit applicability to multilingual learners who represent an increasing proportion of elementary school populations. Fourth, while the study controlled for general cognitive ability, additional cognitive factors such as working memory, attention, and executive function may mediate the relationship between processing speed and academic achievement. Future research should examine these potential mediating mechanisms to better understand the pathways through which processing speed influences learning outcomes.

## CONCLUSION

This comprehensive investigation of the relationship between language processing speed and elementary school learning performance provides compelling evidence for the critical role of processing efficiency in academic achievement. The study demonstrates that specific processing speed measures, particularly those related to reading fluency and arithmetic fluency, serve as stronger predictors of academic success than general processing speed indicators. The two-factor structure of processing speed, distinguishing between simple and complex components, offers important insights into the cognitive mechanisms underlying academic performance, with complex processing speed showing particular importance for higher-order academic skills.

The findings reinforce concepts from the theoretical literature regarding the multifaceted nature of processing speed and its differential contributions to academic outcomes. The superior predictive power of domain-specific processing measures supports theoretical models emphasizing the importance of specialized cognitive systems in academic learning. The developmental patterns observed across elementary grade levels align with previous research while providing new insights into the timing and magnitude of processing speed effects on academic achievement.

The importance and potential impact of these research findings extend beyond theoretical contributions to practical applications in educational settings. The identification of specific processing speed components that most strongly predict academic success provides guidance for educational assessment practices and early identification procedures. The demonstration that processing speed deficits have cascading effects across academic domains suggests that targeted interventions addressing processing efficiency may yield broad benefits for student learning outcomes.

The correlation of evidence for hypotheses from the introduction with discussion findings demonstrates strong support for the proposed relationships between language processing speed and academic achievement. The hypothesis that specific processing speed measures would show stronger relationships with academic outcomes than general processing measures was strongly supported, as was the prediction that complex processing speed would be particularly important for higher-order academic skills.

Future research should address the limitations identified in this study by employing longitudinal designs to examine causal

relationships and developmental trajectories over time. Investigation of mediating mechanisms, including working memory and executive function, would enhance understanding of the pathways through which processing speed influences academic achievement. Additionally, research examining the effectiveness of processing speed interventions in elementary school settings would provide important guidance for educational practice. Studies including diverse populations, particularly multilingual learners, would enhance the generalizability of findings and inform educational practices in increasingly diverse school settings.

## ACKNOWLEDGMENTS

The authors gratefully acknowledge the participating schools, students, and families who made this research possible. We thank the research assistants who contributed to data collection and the teachers who facilitated access to student participants. Special appreciation is extended to the school administrators who supported this research initiative and provided valuable insights into the practical implications of the findings.

## CONFLICT OF INTEREST

The authors declare no conflict of interests related to this research. This study was conducted independently without funding or support from organizations that might have competing interests in the research outcomes.

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