Predictive Relationship Between Phonological Processing Abilities and Reading in Arabic: A Cross-Sectional Study

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Abstract: This cross-sectional study examined the respective role of phonological processing abilities, phonological awareness, rapid naming and short-term memory in the prediction of word reading performance, A total of (210) Arabic speaking children from grades 2, 3, 4 and 5 took part in this study, Results showed significant differences in phonological processing abilities as function of Grade as fixed factor, Phonological awareness was the strongest predictor of reading ability in the whole sample after controlling for Age; The results point to a unique connection between phonological processing and word reading ability based on their underpinning with phonological representation.

Keywords: phonological processing; developmental dyslexia; Arabic language

ملخص: تناولت هذه الدراسة المستعرضة الدور الخاص بمهارات المعالجة الصوتية التي تشمل الوعي الصوتي والتسمية السريعة والذاكرة قصيرة المدى اللفظية، للتنبؤ بأداء قراءة الكلمات، شارك في هذه الدراسة (210) تلميذا من الصفوف الدراسية الثانية، الثالثة، الرابعة والخامسة، خضع جميع أفراد العينة لاختبار قراءة الكلمات وشبه الكلمات، اختبارات الوعي الصوتي والذاكرة اللفظية قصيرة المدى والتسمية السريعة. أظهرت النتائج اختلافات جوهرية في قدرات المعالجة الصوتية راجعة لمتغير المستوى الدراسي، كما أظهر تحليل الانحدار أن الوعي الصوتي يمثل أقوى مؤشر على الأداء في القراءة لدى العينة ككل وذلك بعد عزل أثر السنة، تشير النتائج إلى وجود علاقة فريدة بين المعالجة الصوتية والقدرة على قراءة الكلمات كون هذه الأخيرة تعتمد بشكل أساسي على التمثيلات الصوتية للغة.

الكلمات المفتاحية: المعالجة الفونولوجية; عسر القراءة النمائي; اللغة العربية.

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1- Introduction

Research on the underlying cognitive processes associated with reading acquisition supports the strong association between phonological processing abilities and reading performance (Peterson & Pennington, 2012; Shaywitz & Shaywitz, 2005; Snowling, 2000). The term phonological processing refers to a person's ability to perceive, store, retrieve, and manipulate sounds for language (Serry, Rose, & Liamputton, 2009). Therefore, phonological processing abilities allow children to acquire phoneme-grapheme mapping as well as storing phonological information in memory necessary for learning to decode written words (Kamhi & Catts, 2012).

1.1- Theoretical framework

1.1.1. Phonological Processing and Reading

The term phonological processing is often used to refer to a wide range of cognitive skills involving speech sounds, Basic phonological processing skills, including phonological awareness, phonological memory, and the retrieval of phonological codes from long-term memory (rapid automatized naming, RAN) (Wagner & Torgesen, 1987), have been identified as strong predictors of reading attainment (Castles & Coltheart, 2004), Although PA and RAN are well-established in a large number of orthographies, it is yet unclear whether their predictive patterns are constant across grade levels, According to the phonological representations hypothesis (Swan & Goswami, 1997), the basic deficit in the representation of sound structures of words is primarily reflected in deficits in implicit and explicit phonological tasks, Implicit phonological processing is automatically engaged and requires access to phonological codes without any explicit reflection on the phonemic structure of words, such as verbal short-term memory (VSTM) or RAN tasks (Melby-Lervåg & Lyster (2012), In contrast, explicit phonological processing, usually related to PA tasks, requires the reflection upon and the manipulation of the sound of words.

Phonological awareness (PA) refers to the skill of knowing that oral language has a structure of sounds separate from meaning, and to detect or manipulate the sounds of spoken words (Anthony & Francis, 2005),There is ample evidence showing that becoming a skilled reader requires developing a level of phonological sensitivity to the sound segments of speech (Liberman, Liberman, Mattingly, & Skankweiler, 1980), The quality of phonological representations, referring to how well a sound is differentiated from other sounds in the language, and its role in phonemic awareness is also crucial in reading development (Goswami, 2000), Given this rich body of research on the phonological contributions to reading, there is a consensus that phonological structure of one's language is strongly linked to both reading development (Lonigan, Burgess, & Anthony, 2000) and reading disability (Pennington & Lefly, 2001).

Phonological recoding in lexical access requires rapid retrieval of phonological codes from a long-term store, which has been traditionally assessed by rapid automatic naming (RAN) tasks such as naming a series of digits, letters or colours, RAN, sometimes referred to as naming speed or rapid naming, is the speed with which one can name visually-presented familiar stimuli such as letters, numbers, colours and objects out loud, and reflects the automaticity of processes which are also important for reading (Norton & Wolf, 2012), RAN has also been found to correlate highly with reading achievement (Bowers & Wolf, 1993) and reading disability (Wolf et al., 2000), It is worth noting that some researchers measure naming speed by reporting the time it taken to name the stimuli ignoring the number of errors whereas other researchers reported the naming speed efficiency by dividing the number of errors by the time it took to name the stimuli.

The relationship between RAN and different reading measures has been broadly investigated in the literature, For example, naming speed was found to be correlated with word reading accuracy, word reading speed, text reading speed, pseudoword reading accuracy, and pseudoword reading speed, and shown to be predicted by naming speed (Georgiou et al.,

2008; Landerl & Wimmer, 2008; Moll, Fussenegger, Willburger, & Landerl, 2009), While RAN has been associated with various component reading skill, its strongest relationship is found with reading fluency (Kirby et al., 2003; Savage & Frederickson, 2006), Some researchers have posited that RAN scores make unique contributions to the reading process independent of phonological processing (Wimmer & Mayringer, 2002; Wolf et al., 2000).

1.1.2- Phonological Processing and Reading in Arabic

Saiegh-Haddad (2005) examined the contributions of phonological awareness, rapid automatized naming (RAN), and phonological memory (PM) to letter recoding speed and pseudoword decoding fluency in (42) Arabic-speaking first graders. She found that PA only indirectly predicted fluency through its influence on letter recoding speed, One of the key findings in this study was that letter recoding speed and accuracy was the strongest predictor of reading fluency of vowelized Arabic, When the influence of letter recoding speed was controlled, PM was the strongest predictor of reading fluency, followed by RAN, Obviously the speed of converting graphemes into phonemes stood out as the primary predictor of reading fluency among first graders despite the diglossic effect. In a cross-sectional study of (171) Arabic-speaking children from Grades (1-3) in Bahrain, Al-Mannai and Everatt (2005) reported that measures of PA predicted real word reading and spelling amongst young Arabic learners, Children were tested on numerous measures including single word reading pseudoword reading, spelling, phonological awareness, short-term memory, speed of processing, and non-verbal ability, The authors found that phonological skills measured by pseudoword decoding and PA tasks were the best predictors of reading and spelling, As noted in previous studies, these authors also found differences in predictors between Grade (1) children and Grade (3) children. For the younger children, pseudoword reading was a stronger predictor of reading and spelling whereas word recognition was a stronger predictor of reading and spelling in the older children.

In a cross-sectional study, Taibah and Haynes (2011) investigated the correlational and predictive relationship between different phonological processing abilities and early reading development amongst (237) Arabic-speaking children from K-3, The researchers investigated whether the powers of PA, RAN, and phonological memory in predicting reading abilities vary as a function of grade, The variables of interest included: PA (elision and blending) RAN (52) (object, color, letter, and digit), and phonological memory (pseudoword repetition and digit span), and their contribution to basic decoding and fluency skills in Arabic measured by word decoding, pseudoword reading fluency, and retell fluency, Using a set of regression analyses, the researchers found that after PA was entered, RAN was left to explain a small but significant amount of variance that increased with age, Further, RAN's capacity to predict word recognition, pseudoword reading fluency, and oral reading fluency was most evident in the third graders' reading performance, In another set of regression analyses, the researchers entered RAN as the second variable followed by PA (after controlling for gender, language exposure, and cognitive ability), Taibah and Haynes reported that when word recognition or pseudoword reading fluency were the outcome variables, the predictive power of RAN increased by grade and explained more variance than PA by Grade 3, In kindergarten and Grade 1, PA accounted for more variances in these word-level outcomes than did by RAN, In summary, PA proved to be a significant predictor of unique variance in all of the reading outcomes-recognition, decoding, fluency, or comprehension, When children read lists of words, whether real or pseudowords, the predictive power of PA was highest in the early grades, decreased in second, but caught up again by Grade 3, However, reading text showed different results with PA contributing greater variance in early grades while RAN contributed greater variance in later grades. These results were also supported when RAN was entered before PA; that is, PA still explained significantly high amounts of variance that were not explained by RAN in first and second grades; however, the predictive power of RAN increased by third grade and exceeded PA's predictive power which is in accordance with findings reported by Kirby et al (2003), Al Mannai and Everatt (2005) conducted a study on

the relationships between reading and spelling skills of grades 1–3 Arabic-speaking children and phonological processing skills, Children were tested on their literacy skills (single word reading and spelling), non-word decoding and measures of phonological awareness, short-term memory, speed of processing and non-verbal ability, These tests were included to identify the best predictors of literacy skills amongst Arabic young readers, The results were consistent with the literature in that measures of phonological skills (decoding and awareness) were the best predictors of variability in reading and spelling among the Bahraini children. The results are discussed in terms of the literacy experiences of the children and the use of short vowels in Arabic writing.

Layes et al (2022) examined the role of phonemic awareness (PA), rapid naming (RAN), and verbal short-term memory (VSTM), phonological verbal fluency (PVF) along with literacy related skills (letter naming and orthographic knowledge) in reading, spelling and numeracy performances, The study was carried out on a sample that consists of 245 native Arabic children of grade 1 and 2, The results showed a significant effect of Group on PA, RAN, VSTM, PVF, and letter naming and orthographic knowledge, There is also a comorbidity effect on PA and orthographic knowledge, The regression analysis indicated that PA and orthographic knowledge are the strongest predictors of the three academic outcomes whereas VSTM, PVF and RAN displayed less predictive relationships with reading, spelling and numeracy, The results suggest that there are a number of underpinning factors that are linked to PA and orthographic knowledge, which are also accounted for a comorbidity condition between literacy and numeracy.

In the current study, we hypothesised that: 1) PA, RA, and VSTM differ significantly across grades, and 2) each of these phonological processing abilities could make an individual significant contribution in the prediction of word and pseudoword reading (composite score) in all participants.

2- Method and Tools:

2.1- Participants

In total, 210 students from grades 2 to 5 took part in the current study (n values from grade 2= 48; grade 3= 52; grade 4= 51, In the initial sample, a number of children were excluded, having repeated their academic year or obtained a low score on Raven Standard Progressive Matrices, or else suffered from behavioural disabilities including speech disorders, evidence of visual or hearing impairment, or a history of other neurological or psychiatric disorders, All participants were screened in their schools where teaching is mainly provided in Standard Arabic, All children received an identical literacy instruction program based on the same textbook. Children and their parents were informed of the purpose of the study and the consent to take part was approved. Participants were tested individually, and no limit time was set.

2.2- Materials

Raven test

The Raven Standard Progressive Matrices is a nonverbal test of reasoning ability and general intelligence, We used the shortened form (Bouma et al., 1996), comprising 36 items (sets A, B and C) and consisting of a target matrix with one missing part, The children selected from six to eight alternatives to fill the missing patch.

Word and pseudo-word reading tasks

A list of 80 frequent and infrequent words was given and read aloud (Layes et al., 2015; Layes et al., 2017), The words varied in frequency (high and low) and length (di-syllabic and tri-syllabic), In addition, 40 pseudo-words, controlled for orthographic length were used (Authors, 2015), The internal consistency reliability of the test in this study was high ($\alpha = 0.82$).

Phonological awareness

The phoneme deletion test was used to evaluate PA (Castles & Coltheart, 2004). Fifteen words were presented orally one by one and participants were instructed to isolate the initial syllables from each word and pronounce the remaining part after removing the specified syllable (Layes et al., 2015), The phoneme to be deleted occurred in different positions (beginning, middle and the end) of the word, Words included clusters of consonants (CVCVC), since Arabic words are trilateral.

Rapid Automatized Naming: RAN objects.

A RAN task elaborated from a previous study (Layes et al., 2015) developed to measure lexical retrieval speed of visually presented objects (Wolf & Bowers, 1999), The RAN object task allows us to assess direct access to the phonological representations of real lexical units (i.e., entire words), Participants then named as quickly as possible recurring objects (scissors, cat, book, pen, and hand) arranged semi-randomly in eight rows and repeated 10 times, The time needed to name all of the stimuli was measured. The task was preceded by a short practice session to make sure the child named the presented pictures correctly, The test-retest reliability of the RAN task was adequate (r=.73).

Verbal STM

The forward digit span from the ZAERKI-R battery was used, This task is thought to measure the storage and maintenance of verbal STM with no manipulation of the material. Participants were presented with a series of digits and had to repeat them immediately, If successful, they were given a longer series, The length of the longest list is that person's digit span.

3. Results and Discussion

A multivariate analysis of variance (MANOVA) was conducted to determine possible differences on the phonological processing tasks including PA, RAN and VSTM as dependent variables, with Grade (2, 3, 4 and 5) included as fixed factor, Box's test of equality of covariance was violated ($p < .05$), then Pillai's Trace was used as a more robust against violations of homogeneity of variance.

The omnibus effect for Grade was significant [Pillai's = 0.35, F (12, 61) = 6.83, $p < .001$, partial $\eta^2 = 0.12$]. Follow-up univariate analyses (ANOVAs) showed differences on the group factor in word and pseudoword reading [F (3, 20) = 31.15, $p < .001$, partial $\eta^2 = 0.31$], PA(F (3, 20) = 11.31, $p < .001$, partial $\eta^2 = 0.14$], RAN (F (3, 20) = 11.63, < .001, partial $\eta^2 = 0.14$], and VSTM [F (3, 20) = 4.51, $p = .004$, partial $\eta^2 = 0.06$], These results demonstrate the presence of significant differences in phonological processing abilities between grades**.**

Figure 1. Performance profile in reading and phonological processing abilities by grade

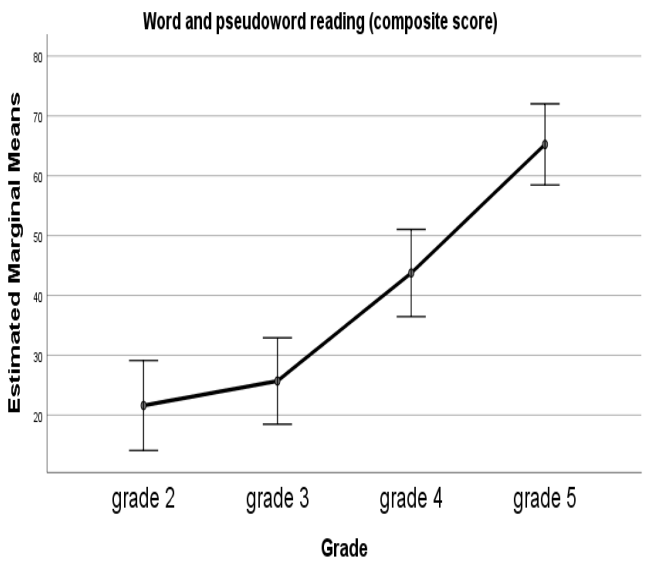

Figure 1 (A). Reading performance by grade

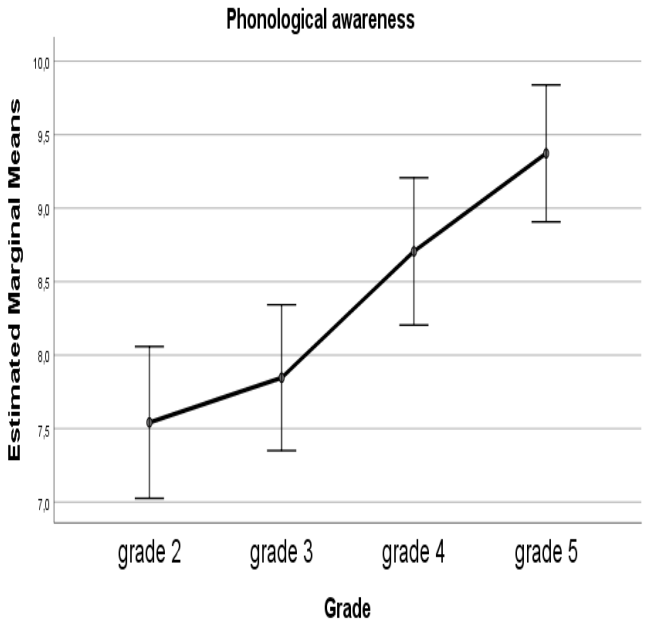

Figure 1 (B). PA performance by grade

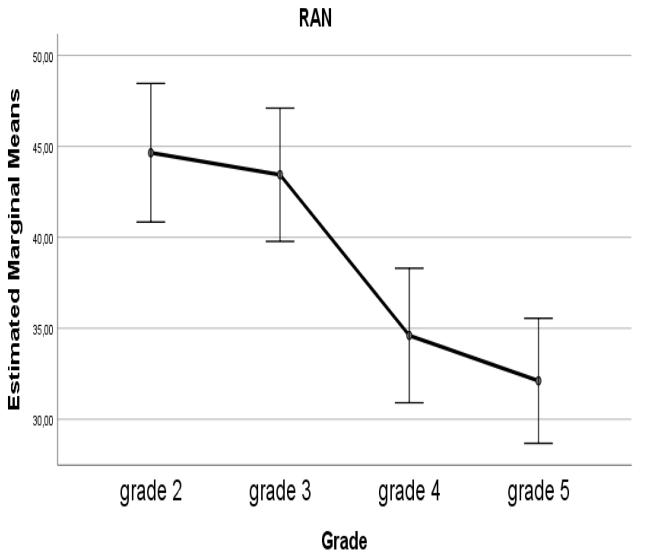

Figure 1 (C). RAN performance by grade

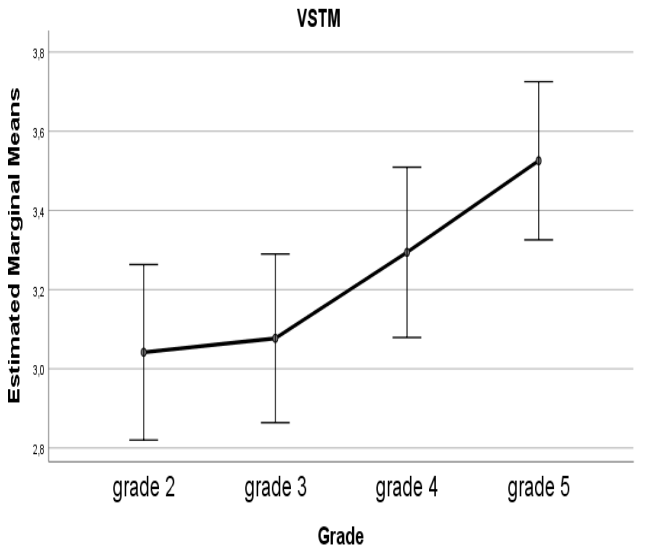

Figure 1 (D). VSTM performance by grade

Table (1): Partial correlations between word and pseudoword reading, and the phonological processing abilities controlling for Age

Variables	Coefficients	1.	2.	3.	4.	5.
Word reading	*r*	_				
	P value					
Pseudoword reading	*r*	0,586	_			
	P value	> 0,001				
PA	*r*	0,585	0,235	_		
	P value	> 0,001	0,002			
RAN	*r*	-0,464	-0,214	-0,340	_	
	P value	> 0,001	0,005	> 0,001		
VSTM	*r*	0,280	0,168	0,303	-0,145	_
	P value	> 0,001	0,028	> 0,001	0,059	

Note. PA = phonological awareness; RAN = rapid automatised naming; VSTM = verbal short-term memory

Furthermore, a hierarchical regression analysis was run on the dependent variables (PA, RAN, VSTM), as an appropriate procedure for the well-studied phonological processing tasks, The results from the regression analysis (Table 2) shows that when Raven is controlled the prediction pattern of reading performance as dependent variable by phonological processing abilities is statistically significant.

Table (2): Summary of hierarchical regression analysis predicting reading performance by phonological processing abilities

Model	Variable	B	Beta	*t*	R^2	R^2 Change	F Change
1	(Constant)	8,398		0,648	0,029	0.029	6,214**
	Age	0,277	,170	2,493*			
2	(Constant)	-10,281		-0,667	0,0396	0.367	41,45***
	Age	,057	,035	0,631			
	PA	6,584	,405	6,631***			
	RAN	-,650	-,296	-5,075***			
	VSTM	4,160	,105	1,798			

Note. * p < 0.05 ; ** p < 0.01 ; *** p < 0.001

As expected, our results showed that participants differed in phonological processing abilities as function of grade, This finding suggests that phonological abilities keep developing as typical children gain upper grades, and therefore, such abilities are primordial for reading and decoding development, Our results replicated previous findings across languages, For example, Al-Jeaid and Taibah (2018) investigated the relationships of phonological processing skills (phonological awareness - rapid naming - phonological memory) and their contributions to selected reading skills (word recognition– fluency of sentence comprehension –text reading fluency– non word reading fluency) in Arabic language in 121 children from third and fifth primary grades The sample also included children with reading disabilities, The results of the T test revealed that phonological processing efficiency distinguishes normally developing children from those with reading disabilities, and phonological awareness was the most important discriminative factor between the two groups in both grades, The results lso showed a moderate to strong relationship between phonological

processing skills (phonological awareness and rapid naming) and reading skills among however phonological memory showed no significant relationships with any of the reading skills.

The importance of phonological processing is also established by the regression analysis indicating that PA and RAN were strong predictors of variability in word reading for the entire sample when Age was statistically controlled, These findings are in agreement with previous studies showing that PA and RAN represent the most relevant precursors of word reading development (e.g., Kirby, Georgiou, Martinussen, & Parrila, 2010; Melby-Lervåg et al., 2012), including reading in Arabic (Abu-Rabia, Share, & Mansour, 2003; Authors, 2015). Consistent with cross-languages studies, most Arabic studies agree that PA is an important factor in reading development (Abu Ahmad et al., 2014; Abu-Rabia et al., 2003; Elbeheri & Everatt, 2007; Saiegh-Haddad & Taha, 2017; Taibah & Haynes, 2011; Tibi & Kirby, 2018). Nonetheless, questions remain regarding the nature of the reading–PA association in Arabic.

Although RAN has been shown as a strong predictor of reading in this study, it is unclear whether this relationship is independent from other underlying factors, Whereas some researchers hypothesized that the relationship between RAN and reading is mediated through phonological awareness (Wagner, Torgesen, & Rashotte, 1994), substantial research has established that RAN consistently accounts for variance in reading beyond the effect of PA (Parrila, Kirby, & McQuarrie, 2004), Other researchers have argued that RAN represents several factors, including processing speed, lower-level visual processes, and higher level cognitive and linguistic processes (Wolf & Bowers, 1999).

Our results are also in agreement with research suggesting that VSTM did not uniquely contribute to reading ability (Mc Dougall & Hulme, 1994), It is likely that the VSTM task is not directly related to variations in children's word reading skill and is only correlated with reading ability because both skills rely on access to phonological information(Melby-Lervåg et al., 2012), According to this view, the VSTM task involves access to the same phonological representations in readingthat underlie PA tasks (Melby-Lervåg & Hulme, 2010), Although the contribution of VSTM to reading ability is still debatable, some reaserchers have suggested that children with a short memory span cannot maintain phonetically-coded material in VSTM well enough to achieve sound segmentation and blending while decoding (e.g. Snowling, 1991), Similar findings were reported in a cross-sectional study by Taibah and Haynes (2011), who investigated whether the predictive relation between different phonological processing abilities and reading accuracy and fluency vary as a function of grade in Arabic-speaking children, The authors found that after PA was entered RAN was left to explain a small but significant amount of variance that increased with age. PA accounted for more variance than RAN regardless of the nature of the outcome in measure and grade, Phonological memory showed almost no relation to reading performance, The authors concluded that requirements of Arabic reading change across age levels (Taibah and Haynes., 2011).

The changing cognitive requirements in learning to read in Arabic seems to be somewhat related to the varying forms of reading acquisition process, Beginning readers in Arabic first learn to read with fully vowelized texts that provide one-to-one letter-to-phoneme connections with all vowels included (i.e., phonologically shallow script), After the first stage of learning to read, children starting from the third and fourth grades are required eventually to read partially and unvowelized texts in which the vowel diacritics are not provided, so that they need to rely on their morphological knowledge and to identify ambiguous words due to incomplete vowel spellings (Abu Rabia, 2001).

4- Conclusion

To sum up,the main findings of the current study showed that PA was the most robust predictor of reading accuracy across grades, followed by RAN objects, Overall our results are in line with the well-established point of view that the phonological hypothesis in reading so far studied across languages makes itself manifest in three main dimensions that rely on the

efficient functioning of the phonological system. These findings may extend previous works on multiple phonological processing abilities that underlie reading mechanisms in children. The contribution of the phonological processing abilities in reading performance tends to vary across grade levels, suggests plausible developmental changes in the relations between phonological processing during reading development.

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