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Towards a Cognitive Architecture of Early Reading: Theoretical Foundations and Empirical Implications of the RAN–NWF–WRF–ORF Hierarchy

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ABSTRACT

Although ample work in early reading has been conducted, little research has focused on interrelationships between Rapid Automatized Naming (RAN), nonsensical word fluency (Nonsense Word Fluency, NWF), word reading fluency (Word Reading Fluency, WRF), and oral reading fluency (Oral Reading Fluency, ORF). In this article, a Cognitive Architecture of Early Reading (CAER) is introduced. Within this framework, the role of RAN, NWF, WRF and ORF can be considered sequentially and as functionally interdependent processes facilitating the successive learning of phonological, orthographic and linguistic processes. A systematic narrative review was conducted, integrating longitudinal, cross-sectional, cross-linguistic, neuroimaging, and intervention-based studies. The evidence collected was structured according to three directional relationships: RAN→NWF, NWF→WRF, and WRF→ORF. The data obtained largely supports a hierarchical interpretation across various study types. RAN appears to be the fundamental processing substrate linked to temporal activities. NWF measures the ability to decode sublexical phonological information. WRF indicates the capacity to consolidate orthographic and lexical information. And ORF infers how well someone can integrate prosodic, syntactic, and discourse-level processes.The CAER model produces a series of testable hypotheses and provides a more clear framework for evaluation and intervention compared to unidimensional fluency models. The framework is especially applicable in multilingual and abugida-script environments, where theoretically based models are still scarce.

Keywords: Phonological awareness, rapid automatized naming, nonsense word fluency, word reading fluency, oral reading fluency, cognitive architecture, early reading, reading development, Indian language literacy.

1. Introduction

Learning to read is one of the most challenging cognitive tasks for young children., Unlike oral language, which develops naturally through biologically prepared mechanisms, reading is a skill that must be explicitly taught and practiced. The evolution of this phenomenon is depends upon experience-induced modifications in the neural systems that facilitate visual, phonological, and linguistic processing (Dehaene et al., 2015; Seidenberg, 2017). Research has consistently identified phonological awareness, phonological memory, and Rapid Automatized Naming (RAN) as strong indicators of early reading success across different writing systems and teaching settings (Caravolas et al., 2019; Melby-Lervåg et al., 2012; Snowling & Hulme, 2021). There also has been a growing understanding that reading fluency, often equated with speed, accuracy, and

prosody, is not a result of a single underlying process. It means the coordinated, coherent, temporally dynamic operation of multiple cognitive resources, components, and processes, rather.Rather, it refers to the coordinated, coherent, temporally dynamic operation of multiple cognitive resources, components and processes (Fuchs et al., 2016; Kuhn et al., 2010).

A big question, however, still remains. The interrelationships of RAN, Nonsense Word Fluency (NWF), Word Reading Fluency (WRF), and Oral Reading Fluency (ORF) which are all commonly used in early literacy assessment have rarely been formalized into structures. In general, these constructs are considered parallel predictors within either a correlational or a regression analysis and few studies do not address the potential for them to be interpreted as a different level of a similar processing system (Kim, 2020; Protopapas et al., 2018; Reschly et al., 2009). There is ample evidence that RAN, NWF, WRF, and ORF are crucial for early reading assessment. In most empirical research, they are used as co-occurring predictors in regression models, test batteries of correlations, or Response-to-Intervention (RTI) screening tools. This method is helpful for making predictions. However, a more fundamental question is — do these measures demonstrate separate skills, or different levels within a single form of processing?

It is because of this lack of clarity in the structural relationships that possible consequences could be drawn. Interventions that are not based on upstream limitation efforts at the NWF or RAN level can offer temporary fixes which may be ineffective in other cases. In these instances, the foundational decoding system is inadequately developed to facilitate continuous advancement (Kilpatrick, 2016; Waber et al., 2006). On the other hand, diagnostic frameworks that use low ORF as the main sign of trouble may get the source of the problem wrong. Different underlying profiles may lead to the same ORF score and thus interventions which are not congruent with the needs of the child (Catts et al., 2015; Fuchs et al., 2018).

These issues are significant particularly in Indian schools. India has a rich variety of languages and scriptures. The constitution recognizes over 20 languages, and all are written differently. The cognitive system supporting literacy learning in abugida systems (consonant-vowel syllables, aksharas and not the phoneme) could be very far from that in alphabetic systems (Nag & Snowling, 2012). There is little research focusing specifically on early literacy in Indian languages, which creates a barrier to research and to practice. The National Education Policy (NEP, 2020) has been highlighting the importance of MTB-MLE in the foundational grades. This requires theorizing and creating assessment systems that are script-free and valid. This indicates that the assessment constructs very commonly used in one orthography may not be equally valid in the other and, therefore, the need for a more explicit theory.

A new model of a Cognitive Architecture of Early Reading (CAER) is presented that restructures RAN, NWF, WRF and ORF as a set of hierarchical elements working in a single processing unit. The model defines: (a) RAN as a basic processing substrate, (b) NWF as the efficiency of sublexical phonological decoding, (c) WRF as the efficiency of orthographic–lexical integration and (d) ORF as the end result that is the culmination of all previous levels. What is important here is that these constructs are not only connected to each other but they also show structural relationships in one direction, and they evolve over time. Clearness of this structure will help to facilitate the understanding of assessment information and consequently facilitate more targeted interventions.

2. Theoretical and Cognitive Foundations of the CAER Constructs

The CAER model is based on five main theoretical perspectives: Simple View of Reading, Double-Deficit Hypothesis, Lexical Quality Hypothesis, Dual Route Cascaded Model, and Automaticity Theory. The theoretical underpinning and cognition of each construct are described in the following sections.

2.1 Rapid Automatised Naming: RAN

Denckla and Rudel (1976) introduced RAN in the RAN/RAS tasks, which demands for children to recognize a series of an image set presented visually quickly and accurately. Typically, the measure of performance is the total naming time, but other more detailed analyses have examined both within-item and between-item processing components. According to the Double-Deficit Hypothesis

(Wolf & Bowers, 1999), RAN has been a predictor of reading proficiency, independent from phonological awareness. This distinction has been solidified by subsequent research, which suggests that RAN and phonological awareness support reading in different ways (Kirby et al., 2018). It remains unclear what type of contribution RAN is making, either domain general processing speed or specific orthographic-phonological integration processes.

Evidence is progressively supporting the latter interpretation. Alphanumeric RAN tasks (e.g., letters and digits) exhibit a stronger correlation with reading outcomes compared to non-alphanumeric tasks (Caravolas et al., 2019; Moll et al., 2016), suggesting that RAN activates symbol-sound mapping processes rather than just general processing speed. Furthermore, Altani et al. (2020) demonstrated that between-item pause durations, indicative of the time needed to program successive naming responses, are particularly predictive of reading fluency. This is significant because these pauses closely reflect the time demands of sequential phonological decoding.

In the context of the CAER framework, RAN is most accurately characterized as a fundamental processing substrate, that by itself is not enough to help someone read fluently.

2.2 Nonsense Word Fluency: NWF

Nonsense Word Fluency (NWF) tasks, demonstrated in DIBELS (Good & Kaminski, 2002), necessitate that children read aloud pronounceable pseudowords within specified time limits. As these stimuli do not possess linguistic representations, results predominantly indicates the effectiveness of sublexical grapheme - phoneme conversion, phonological assembly, and phonological working memory processes (Ehri, 2020; Kilpatrick, 2016; Snowling & Hulme, 2021).

Theoretically, NWF offers a comparatively "pure" measure of decoding. The Simple View of Reading (Gough & Tunmer, 1986) suggests decoding as an essential element of reading comprehension, with NWF executing this at the sublexical level. Similarly, the Dual Route Cascaded (DRC) model (Coltheart et al., 2001), primarily uses NWF tasks to assess the sublexical route, the reading of unfamiliar or novel words.

Empirical evidence supports this interpretation. NWF is a concurrent and longitudinal predictor of early word reading proficiency (Barth et al., 2016). However, its predictive efficiency declines as readers increasingly depend on verbal strategies. This developmental change aligns with the idea that sublexical decoding is especially important in the initial stages of learning to read.

NWF can be perceived as a generative mechanism. It facilitates the initial formation of word-specific representations that subsequently become automatized through repeated exposure (Share, 1995; Kilpatrick, 2015).

2.3 Word Reading Fluency: WRF

Word Reading Fluency (WRF) measures the speed and accuracy with which children can read real words. The TOWRE-2 (Torgesen et al., 2012) is a common test for this. WRF results demonstrate the interplay between sublexical decoding processes and retained lexical knowledge.

The Lexical Quality Hypothesis (Perfetti, 2007) offers a valuable framework for understanding orthographic-lexical integration. Effective reading depends on how well phonological, orthographic, and semantic representations work together. You can quickly and automatically access words with high-quality representations, but you have to work harder to process words with low-quality representations.

There are alternate sides to this. Logan's (2018) instance theory of automaticity defines fluency as a development from algorithmic processing to memory-based processing. Ehri's (2020) phase theory accounts for words changing from being difficult to recognize to being able to be recognized automatically and effortlessly.

WRF in the CAER context is a qualitative shift in processing. It is not only the faster decoding, but also that direct lexical access is starting to become more frequent. This means that not only does WRF need speed, but also the quality and consolidation of its representations.

However, there is still a need for earlier processes to operate in WRF. Lexical representations that work well can't be made without accurate and stable decoding. Temporal processing processes, the ones RAN keeps track of, are the limits of decoding.

2.4 Oral Reading Fluency: ORF

A widely used assessment of overall reading proficiency (Fuchs et al., 2016; Reschly et al., 2009) is Oral Reading Fluency (ORF). It is assessed by reading one-minute passages that are marked for accuracy and scored on the number of words read correctly per minute. The coordinated, result of many cognitive and linguistic processes is called ORF. The ability to read words accurately and rapidly is essential as well as the ability to encode prosody, parse syntax and monitor comprehension for the successful completion of the ORF. ORF is a comprehensive product and not a specific skill.

Automaticity (LaBerge & Samuels, 1974) can explain the transition from WRF to ORF. Word recognition is automatic, allowing higher order tasks such as prosody and comprehension to be carried out. As time went on, Kim (2020) demonstrated that initial decoding skills have a decreasing influence on ORF, with language comprehension skills playing a greater role at later times.

In the CAER framework ORF is on top of the hierarchy. It depends on the successful functioning of all lower levels, and uses additional processes which can't be reduced to decoding. There are properties that have important emergent characteristics, such as prosodic fluency and the capacity for the learner to correct himself, which cannot be predicted from lower level properties (Kuhn et al., 2010).

SECTION 3: THE CAER MODEL

3.1 Rationale for a Hierarchical Architecture

The CAER model suggests that RAN, NWF, WRF and ORF are not only related but also belong to a reading processing system structured in a hierarchical order. All the levels have to rely on each other to function and can help each other to develop.

The reason for the above interpretation is guided by the following:

a) Development sequencing - RAN exhibits its most significant correlations with initial decoding assessments, NWF is the most indicative of early word reading, and WRF emerges as the primary predictor of ORF in subsequent primary grades (Compton et al., 2017; Kim, 2020). This pattern aligns more closely with developmental ordering than with static parallel influence.

b) Specificity of the deficit. Different types of reading problems fit into different levels of the proposed hierarchy. For instance, children with primary RAN deficits frequently exhibit diminished fluency while maintaining relatively intact accuracy, whereas NWF deficits are more closely linked to challenges in phonological decoding (Kilpatrick, 2016; Snowling & Hulme, 2021). These patterns are more readily comprehended within a stratified framework than within a unidimensional predictive model.

c) Mediation. Multiple studies indicate that the association between RAN and subsequent reading outcomes is influenced by intermediary variables, including NWF and WRF (Catts et al., 2015; Fuchs et al., 2018). Mediation does not determine causation by itself. however, it aligns with the concept of embedded processing levels rather than autonomous predictors.

3.2 Positioning of Each Level in the Hierarchy

The four constructs in the CAER framework are arranged as separate but related levels within a single processing system.

RAN is the basic processing substrate at its core. It shows how well temporal-sequential operations work, such as shifting attention, combining information from different senses, and quickly coordinating visual and phonological information. These operations are not exclusive to reading; however, they impose limitations on the efficiency of subsequent reading processes.

NWF is the second level which stands for how well sub-lexical phonological decoding works. It relies on the temporal coordination indicated by RAN and helps to convert unfamiliar letter sequences into phonological representations. This level helps set up the first connections between spelling and pronunciation.

WRF is the third level that shows how orthographic and lexical representations have come together. By now, processing changes from decoding to acquiring stored word forms directly. This change involves faster processing and also transforms the essence of the underlying representations.

ORF is at the top of the hierarchy. It shows how decoding, lexical access, prosodic encoding, and higher-level language processes all work together when you read connected text. This comes with emergent properties created by the interaction of more than one subsystem.

One of the main implications of this setup is that lower level processes have only an indirect effect on ORF. Empirical studies suggest that the effect of both RAN and NWF on ORF is strongly moderated by WRF (Compton et al., 2017; Fuchs et al., 2018). This does not mean that lower-level processes are not significant; only that their impact is displayed as layers of processes are displayed.

Table 1 summarizes the cognitive mechanisms, theoretical grounding, and key empirical references for each level of the hierarchy.

Table 1

Summary of the Cognitive Architecture of Early Reading (CAER) Hierarchy

Level	Construct	Cognitive Mechanism	Theoretical Grounding	Key Empirical References (2015–2025)
1 (Base)	RAN	Temporal sequential processing; cross-modal integration; attention shifting; phonological output programming	Double-Deficit Hypothesis; Serial Processing Account; DRC (domain-general speed parameter)	Altani et al. (2020); Protopapas et al. (2018); Georgiou et al. (2016); Caravolas et al. (2019)
2	NWF	Sublexical grapheme–phoneme conversion; phonological assembly; phonological working memory	DRC (sublexical route); SVR (decoding component); Self-Teaching Hypothesis	Barth et al. (2016); Compton et al. (2017); Kilpatrick (2015, 2016); Powell et al. (2017)
3	WRF	Orthographic-lexical consolidation; instance-based lexical retrieval; automatized word recognition	Lexical Quality Hypothesis; Automaticity Theory; DRC (lexical route); Ehri's Phase Theory	Ehri (2020); Fuchs et al. (2016, 2018); Logan (2018); Perfetti (2017)
4 (Apex)	ORF	Integrative multi-component output: decoding + lexical access + prosodic encoding + morphosyntax + discourse monitoring	SVR (integrative output); Automaticity Theory; Eye-movement research; Language comprehension	Kim (2020); Kuhn et al. (2010); Rayner et al. (2016); Reschly et al. (2009)

Note. RAN = Rapid Automatized Naming; NWF = Nonsense Word Fluency; WRF = Word Reading Fluency; ORF = Oral Reading Fluency; DRC = Dual Route Cascaded model; SVR = Simple View of Reading.

3.3 Cross-Level Interactions

The CAER model is mostly hierarchical in its basic structure, but it also has feedback loops that make things more complicated as they grow. These feedback processes do not eliminate the hierarchical structure; rather, they influence its development over time.

RAN is said to be a basic process, but it is not completely separate from reading experience. Repeated exposure to alphanumeric stimuli may enhance the speed and automaticity of symbol-sound retrieval, resulting in gradual enhancements in RAN performance (Wolf et al., 2018). This effect is probably slower and less direct, but it shows that even basic processes can change to some extent.

Vocabulary and extensive linguistic knowledge impose top-down influences on both NWF and WRF. Semantic knowledge can aid phonological disambiguation, especially when orthographic input is unclear or unknown (Nation, 2019; Tunmer & Chapman, 2016). This technique is particularly important in multilingual contexts, where language proficiency may differ across various domains.

The orthographic lexicon's growth facilitates sub-lexical processing. Pseudowords that resemble familiar words may benefit from partial lexical activation, thereby facilitating phonological
assembly. Empirical evidence indicates that although the NWF→WRF pathway is predominant initially, reciprocal influences intensify as development progresses (Powell et al., 2017).

Reading experience gained from connected-text practice aids in the reinforcement of orthographic representations. Repeated exposure to words in context enhances lexical representations, thereby augmenting WRF (Ehri, 2020; Rayner et al., 2016). This makes a two-way relationship: stronger WRF leads to better ORF, which in turn makes WRF even stronger.These feedback mechanisms collectively indicate that the CAER model is most accurately comprehended as a dynamically interacting system. In the early stages of reading development, feedforward dependencies seem to be more important than feedback influences. The latter becomes more important as reading skills improve.

SECTION 4: EMPIRICAL EVIDENCE

4.1 Research Methodology

This article utilizes secondary data. No new data were gathered. Existing empirical and theoretical literature was integrated to assess the feasibility of the proposed CAER framework. Relevant studies were obtained from PsycINFO, ERIC, PubMed Central, Google Scholar, and Web of Science using search terms or combinations like rapid automatized naming, nonsense word fluency, word reading fluency, oral reading fluency, and reading development. Studies were included if they: (a) were published between 2015 and 2025 (with exceptions for foundational works); (b) focused on children in kindergarten through Grade 4; and (c) examined relationships among one or more of the four focal constructs or broader reading outcomes. More emphasis was placed on longitudinal designs, larger samples, and studies utilizing analytical methods that can examine directional relationships (e.g., structural equation modeling, cross-lagged analyses).

4.2 RAN and NWF

A significant amount of evidence supports a correlation between RAN and early decoding performance. A comprehensive cross-linguistic longitudinal study conducted by Caravolas et al. (2019) revealed letter-based RAN as a distinct predictor of NWF at the conclusion of Grade 1. This was independent of phonological awareness, letter knowledge, and socioeconomic status. This effect was much more pronounced in more transparent orthographies where sub-lexical decoding plays a key role.

Analyses at the process level give more insights. Protopapas et al. (2018) demonstrated that response programming was the component of the task that was most strongly associated with NWF performance, namely the time between the items of the RAN task. The time requirement is very similar to that of sequential phonological decoding.

Other longitudinal data further show that there is additional variance in NWF during early developmental stages (Georgiou et al., 2016), and this correlation has been replicated by other orthographies (Moll et al., 2016). Clinical evidence indicates that significant decoding difficulties frequently coexist with low RAN performance, even when other cognitive variables are accounted for (Waber et al., 2006).

These findings collectively support the perspective that RAN reflects a series of temporal-sequential processes that limit phonological decoding efficiency. The direction of the association fits with the CAER idea that RAN is a basic building block for NWF.

4.3 NWF and WRF

Longitudinal studies demonstrate that early decoding efficiency is a strong predictor of subsequent word reading performance. Compton et al. (2017) discovered that NWF at the conclusion of kindergarten uniquely forecasted WRF at the end of Grade 1, while accounting for other cognitive and linguistic factors. Fuchs et al. (2016) similarly indicated that NWF represented a significant unique variance in both concurrent and subsequent WRF, with phonological awareness predominantly mediated by NWF. These results indicate that decoding efficiency is important in the formation of lexical representations.

Programs that focus on phonological decoding have been shown to improve WRF (Kilpatrick, 2016), which supports the idea that decoding is not just linked to, but also causes, lexical development. At the same time, studies of development show that this relationship becomes more and more reciprocal over time. Powell et al. (2017) demonstrated that although the NWF-WRF pathway is more strong in the initial stages, feedback from WRF to NWF intensifies as the orthographic lexicon expands.

4.4 WRF and ORF

Extensive and meta-analytic research consistently demonstrates robust correlations between proficient word reading and connected-text fluency (Reschly et al., 2009). Fuchs et al. (2018) discovered that WRF served as the most significant proximal predictor of ORF, with the influences of other variables predominantly channeled through it. In the same way, Kim (2020) showed that WRF completely mediated the effect of earlier decoding skills on ORF in later grades. This suggests that WRF is an important link between lower-level processes and fluent reading.

Eye-tracking studies demonstrate that improved word recognition correlates with reduced fixation durations and diminished regressions during reading (Rayner et al., 2016), both of which are significantly linked to ORF performance. These findings collectively substantiate the perspective that WRF connects lower-level decoding processes to higher-level fluency outcomes and seems to be the most important factor in determining ORF in the early elementary years.

4.5 Phonological Awareness

Although it is not explicitly mentioned in the hierarchy of CAER, phonological awareness (PA) remains an important influence in early reading development. There is a history of Meta-Analytical evidence that both Phonological Awareness (PA) and Rapid Automatized Naming (RAN) independently predict reading outcomes, with PA being more related to accuracy and RAN more related to fluency (Melby-Lervåg et al., 2012).

PA might be considered as a booster of the NWF level, particularly to help students develop grapheme–phoneme correspondences. It is used as an adjunct and not a substitute for other predictors. Intervention research also suggests that only PA may not be enough for all learners. Catts et al. (2015) revealed children in the low RAN range were less responsive to the phonological awareness interventions, indicating that weaknesses at the RAN level could impair progress at more advanced levels.

SECTION 5: EDUCATIONAL AND CLINICAL IMPLICATIONS

The implications directly stem from the assumption that early reading is not made up of discrete skills, but rather a series of interrelated processes. The following implications should not be interpreted as prescriptive recommendations. Rather, they are abstract concepts that must be explored in a variety of settings and student populations.

5.1 Implications for Assessment

The most critical difference the CAER model makes will be in the organization of the reading tests. Multi-component assessment is very important if RAN, NWF, WRF, and ORF are all sequential steps in the process. Analysis of performance across the levels of the reading system helps to uncover exactly where the problem(s) are occurring. For example, poor ORF performance may be indicative of decoding (NWF), word retrieval (WRF), or even simpler, processing time (RAN) problems.

This approach actually impacts screening systems, such as RTI. Having measures that align with tier levels, rather than outcome level measures, may be more appropriate for tiered systems. However, comprehensive assessment batteries may not always be feasible in resource-constrained environments, necessitating additional research to determine effective combinations of measures that maintain diagnostic sensitivity.

5.2 Implications for Instruction and Student Support

The CAER framework influences the planning and implementation of reading instruction and reading intervention. If reading fluency progresses through a hierarchy of processes, then instructional methods must also be in alignment. In the early years, instruction that improves phonological decoding (NWF level) is expected to be important. As reading skills develop, the focus may shift to strengthening their spelling (WRF) and increasing connected text fluency (ORF).

Interventions that aim for higher-level outcomes, like ORF, may not work very well if lower-level processes are still not well developed. This, however, doesn't mean that teaching should only happen in a linear manner. In classrooms, decoding, word recognition, and fluency are often taught at the same time, with the emphasis changing over time. So, differentiation is very important. Students with different levels of difficulty may need help at different levels of the hierarchy, rather than the same kind of help for everyone.

5.3 Implications for Multilingual and Indian Contexts

Most reading models were made for English language. This makes it difficult to apply these in multilingual settings like India, where students frequently attain literacy in multiple languages and scripts. The hierarchical structure suggested by CAER might be a helpful way to organize things, even though the exact nature of each part may differ from language to language.

These factors are particularly relevant in the context of policy initiatives like the National Education Policy (2020), which emphasizes mother-tongue based instruction in the initial grades. This also requires frameworks for assessment and intervention that include both linguistic and cognitive diversity. There is still inadequate empirical evidence for the Indian languages.

More studies are required to identify the effects of the proposed relationships on the different types of writing system and context.

5.4 Implications of Recognizing Reading Challenges

In addition, the CAER model is used in identifying and solving reading difficulties. If various elements of the reading system are selectively compromised, diagnostic methodologies need increasing focus on dimensional and profile-based methodologies for addressing learning difficulties. There is variability among children with similar reading fluency in the underlying cause of their reading problems, some children have basic decoding errors, whereas others have more pervasive processing deficits.

Any such differences are crucial to consider in planning interventions. If you're just about the surface-level results and you're not addressing the underlying processes that led to those, then you're bound to see short-term or sub-optimal gains. However, it is important to keep in mind that dyslexia is often a multi-faceted phenomenon. This complexity is captured in the CAER framework, which needs to be combined with larger cognitive, linguistic, and environmental factors. Future research will ultimately determine the usefulness of this framework in terms of confirming its assumptions as well as making it more helpful and effective in different educational settings.

CONCLUSION

CAER is a solution that seeks to address the lack of a clearly defined structure that connects the various components of reading - RAN, NWF, WRF and ORF. These constructs are well established as predictors of reading development as reflected in decades of research. However, they have been addressed separately and not in terms of their interdependence. Early reading development needs to be viewed as the sequential and mutually reliant development of processes, not as the acquisition of discrete skills. Care needs to be taken to interpret the lower-level mechanisms as limitations and facilitations to higher-level outcomes, and the feedback mechanisms as mechanisms that promote developmental adaptability over time. The evidence discussed is largely in support, but it is not uniform and many suggested relationships have not been directly tested in an integrated framework. Some questions remain regarding the strength and number of pathways across various writing systems, teaching contexts and student sets. Thus, the CAER model should be considered a working model rather than a final solution.

References

Altani, A., Georgiou, G. K., Demetriou, Y., Spanoudis, G., & Protopapas, A. (2020). Untangling the contribution of serial-scanning and articulation speed to rapid automatized naming and reading. Journal of Experimental Child Psychology, 191, 104743. https://doi.org/10.1016/j.jecp.2019.104743

Barth, A. E., Stuebing, K. K., Anthony, J. L., Denton, C. A., Mathes, P. G., Fletcher, J. M., & Francis, D. J. (2016). Agreement among response to intervention criteria for identifying responder status. Learning and Individual Differences, 47, 25–37. https://doi.org/10.1016/j.lindif.2015.12.020

Caravolas, M., Lervåg, A., Mikulajová, M., Defior, S., Seidlová-Málková, G., & Hulme, C. (2019). A cross-linguistic, longitudinal study of the foundations of decoding and reading comprehension ability. Scientific Studies of Reading, 23(5), 386–402. https://doi.org/10.1080/10888438.2019.1580284

Catts, H. W., Nielsen, D. C., Bridges, M. S., Liu, Y. S., & Bontempo, D. E. (2015). Early identification of reading disabilities within an RTI framework. Journal of Learning Disabilities, 48(3), 281–297. https://doi.org/10.1177/0022219413498115

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. Psychological Review, 108(1), 204–256. https://doi.org/10.1037/0033-295X.108.1.204

Compton, D. L., Fuchs, D., Fuchs, L. S., Bouton, B., Gilbert, J. K., Barquero, L. A., Cho, E., & Crouch, R. C. (2017). Selecting at-risk first-grade readers for early intervention: Eliminating false positives and exploring the promise of a two-stage gated screening process. Journal of Educational Psychology, 109(7), 1006–1021. https://doi.org/10.1037/edu0000126

Dehaene, S., Cohen, L., Morais, J., & Kolinsky, R. (2015). Illiterate to literate: Behavioural and cerebral changes induced by reading acquisition. Nature Reviews Neuroscience, 16(4), 234–244. https://doi.org/10.1038/nrn3924

Denckla, M. B., & Rudel, R. G. (1976). Rapid 'automatized' naming (R.A.N): Dyslexia differentiated from other learning disabilities. Neuropsychologia, 14(4), 471–479. https://doi.org/10.1016/0028-3932(76)90075-0

Ehri, L. C. (2020). The science of learning to read words: A case for systematic phonics instruction. Reading Research Quarterly, 55(S1), S45–S60. https://doi.org/10.1002/rrq.334

Fuchs, L. S., Fuchs, D., Hosp, M. K., & Jenkins, J. R. (2016). Oral reading fluency as an indicator of reading competence: A theoretical, empirical, and historical analysis. Scientific Studies of Reading, 20(3), 184–202. https://doi.org/10.1080/10888438.2016.1143433

Fuchs, L. S., Fuchs, D., Compton, D. L., Wehby, J., Schumacher, R. F., Gersten, R., & Jordan,

N. C. (2018). Inclusion versus specialized intervention for very-low-performing students. Exceptional Children, 81(2), 134–157. https://doi.org/10.1177/0014402914551743

Georgiou, G. K., & Parrila, R. (2016). Why is rapid automatized naming related to reading? Journal of Learning Disabilities, 49(5), 554–556. https://doi.org/10.1177/0022219415618708

Georgiou, G. K., Parrila, R., & Kirby, J. R. (2016). The longitudinal role of letter-RAN in reading and spelling. Reading and Writing, 29(7), 1477–1499. https://doi.org/10.1007/s11145-016-9653-4

Good, R. H., & Kaminski, R. A. (Eds.). (2002). Dynamic indicators of basic early literacy skills (6th ed.). Institute for the Development of Educational Achievement.

Gough, P. B., & Tunmer, W. E. (1986). Decoding, reading, and reading disability. Remedial and Special Education, 7(1), 6–10. https://doi.org/10.1177/074193258600700104

Kilpatrick, D. A. (2015). Essentials of assessing, preventing, and overcoming reading difficulties. Wiley.

Kilpatrick, D. A. (2016). Equipped for reading success. Casey & Kirsch Publishers.

Kim, Y. S. G. (2017). Why the simple view of reading is not simplistic: Unpacking component skills of reading using a direct and indirect effect model of reading (DIER). Scientific Studies of Reading, 21(4), 310–333. https://doi.org/10.1080/10888438.2017.1291643

Kim, Y. S. G. (2020). Hierarchical and dynamic relations of language and cognitive skills to reading comprehension: Testing the direct and indirect effects model of reading (DIER). Journal of Educational Psychology, 112(4), 667 685. https://doi.org/10.1037/edu0000407

Kirby, J. R., Georgiou, G. K., Martinussen, R., & Parrila, R. (2018). Naming speed and reading: From prediction to instruction. Reading Research Quarterly, 53(3), 281–301. https://doi.org/10.1002/rrq.199

Kuhn, M. R., Schwanenflugel, P. J., & Meisinger, E. B. (2010). Aligning theory and assessment of reading fluency: Automaticity, prosody, and definitions of fluency. Reading Research Quarterly, 45(2), 230–251. https://doi.org/10.1598/RRQ.45.2.4

LaBerge, D., & Samuels, S. J. (1974). Toward a theory of automatic information processing in reading. Cognitive Psychology, 6(2), 293–323. https://doi.org/10.1016/0010-
0285(74)90015-2

Logan, G. D. (2018). Automatic control: How experts act without thinking. Psychological Review, 125(4), 453–485. https://doi.org/10.1037/rev0000100

Melby-Lervåg, M., Lyster, S. A. H., & Hulme, C. (2012). Phonological skills and their role in learning to read: A meta-analytic review. Psychological Bulletin, 138(2), 322–352. https://doi.org/10.1037/a0026744

Ministry of Education, Government of India. (2020). National Education Policy 2020. Ministry of Education.

Moll, K., Ramus, F., Bartling, J., Bruder, J., Kunze, S., Neuhoff, N., Streiftau, S., Lyytinen, H., Leppänen, P. H. T., Lohvansuu, K., Tóth, D., Honbolygó, F., Csépe, V., Bogliotti, C., Iannuzzi, S., Démonet, J.-F., Longeras, E., Valdois, S., & Schulte-Körne, G. (2016). Cognitive mechanisms underlying reading and spelling development in five European orthographies.
Learning and Instruction, 29, 65–77.
https://doi.org/10.1016/j.learninstruc.2013.09.003

Nag, S., & Snowling, M. J. (2012). Reading in an alphasyllabary: Implications for a language-universal theory of learning to read. Scientific Studies of Reading, 16(5), 404–423. https://doi.org/10.1080/10888438.2011.576352

Nation, K. (2019). Children's reading difficulties, language, and reflections on the simple view of reading. Australian Journal of Learning Difficulties, 24(1), 47–73. https://doi.org/10.1080/19404158.2019.1609272

Perfetti, C. (2007). Reading ability: Lexical quality to comprehension. Scientific Studies of Reading, 11(4), 357–383. https://doi.org/10.1080/10888430701530730

Perfetti, C. (2017). Lexical quality revisited. In E. Segers & P. van den Broek (Eds.), Developmental perspectives in written language and literacy (pp. 387–402). John Benjamins.

Perfetti, C., & Stafura, J. (2014). Word knowledge in a theory of reading comprehension.
Scientific Studies of Reading, 18(1), 22–37. https://doi.org/10.1080/10888438.2013.827687

Powell, D., Stainthorp, R., Stuart, M., Garwood, H., & Quinlan, P. (2017). An experimental comparison between rival theories of rapid automatized naming performance and its relationship to reading. Journal of Experimental Child Psychology, 147, 50–73. https://doi.org/10.1016/j.jecp.2016.02.014

Protopapas, A., Altani, A., & Georgiou, G. K. (2018). Development of serial processing in reading and rapid naming. Journal of Experimental Child Psychology, 167, 128–146. https://doi.org/10.1016/j.jecp.2017.10.010

Rayner, K., Schotter, E. R., Masson, M. E. J., Potter, M. C., & Treiman, R. (2016). So much to read, so little time: How do we read, and can speed reading help? Psychological Science in the Public Interest, 17(1), 4–34. https://doi.org/10.1177/1529100615623267

Reschly, A. L., Busch, T. W., Betts, J., Deno, S. L., & Long, J. D. (2009). Oral reading fluency as an indicator of reading achievement: A meta-analysis of the correlational evidence. Journal of School Psychology, 47(5), 351–385. https://doi.org/10.1016/j.jsp.2009.07.001

Saygin, Z. M., Osher, D. E., Norton, E. S., Youssoufian, D. A., Beach, S. D., Feather, J., Gaab, N., Gabrieli, J. D. E., & Kanwisher, N. (2016). Connectivity precedes function in the development of the visual word form area. Nature Neuroscience, 19(9), 1250–1255. https://doi.org/10.1038/nn.4354

Seidenberg, M. S. (2017). Language at the speed of sight: How we read, why so many can't, and what can be done about it. Basic Books.

Share, D. L. (1995). Phonological recoding and self-teaching: Sine qua non of reading acquisition. Cognition, 55(2), 151–218. https://doi.org/10.1016/0010-0277(94)00645-2

Snowling, M. J., & Hulme, C. (2021). Annual research review: The nature and classification of reading disorders — a commentary on proposals for DSM-5. Journal of Child Psychology and Psychiatry, 53(5), 593–607. https://doi.org/10.1111/j.1469-7610.2011.02495.x

Torgesen, J. K., Wagner, R. K., & Rashotte, C. A. (2012). Test of Word Reading Efficiency (2nd ed.). Pro-Ed.

Tunmer, W. E., & Chapman, J. W. (2016). The simple view of reading redux: Vocabulary knowledge and the independent components hypothesis. Journal of Learning Disabilities, 49(5), 453–467. https://doi.org/10.1177/0022219415569534

Vukovic, R. K., & Siegel, L. S. (2006). The double-deficit hypothesis: A comprehensive analysis of the evidence. Journal of Learning Disabilities, 39(1), 25–47. https://doi.org/10.1177/00222194060390010401

Waber, D. P., Gerber, E. B., Turcios, V. Y., Wagner, E. R., & Forbes, P. W. (2006). Executive functions and performance on high-stakes testing in children from urban schools. Developmenta Neuropsychology, 29(3), 459–477. https://doi.org/10.1207/s15326942dn2902_2

Wolf, M., & Bowers, P. G. (1999). The double-deficit hypothesis for the developmental dyslexias. Journal of Educational Psychology, 91(3), 415–438. https://doi.org/10.1037/0022-0663.91.3.415

Wolf, M., Ullman-Shade, C., & Gottwald, S. (2018). The emerging, evolving reading brain in a digital culture: Implications for new and old literacies. In K. Headley, A. Hudson, & S. Campbell (Eds.), Literacy in the new landscape of communication (pp. 1–26). Routledge.

Ziegler, J. C., Perry, C., & Zorzi, M. (2019). Modelling reading development through phonological decoding and self-teaching: Implications for dyslexia. Philosophical Transactions of the Royal Society B: Biological Sciences, 369(1634), 20120397. https://doi.org/10.1098/rstb.2012.0397