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Cognitive Pathways in Reading: Theoretical Developments from Interactive Models to the Multiple-Processing Account

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Abstract: This critical narrative review examines major theoretical models of reading comprehension, tracing their evolution and evaluating their contributions and limitations in explaining how readers construct meaning from text. Drawing on more than 80 foundational and contemporary studies identified through searches of major academic databases, including Scopus, Web of Science, ERIC, and Google Scholar, the review synthesizes research on cognitive, linguistic, and metacognitive processes involved in reading. Beginning with traditional unidirectional frameworks—bottom-up and top-down models—it highlights their limitations in capturing the complex and interactive nature of skilled reading. The review then examines influential interactive and compensatory frameworks, including Rumelhart's Interactive Model, Stanovich's Interactive-Compensatory Model, Perfetti's Verbal Efficiency Model, Walczyk's Compensatory-Encoding Model, and Just and Carpenter's Capacity-Constrained Reader (CC READER) Model. Particular attention is given to their treatment of working memory, automaticity, compensation, and individual differences. The review further discusses the Multiple-Processing Model as a proficiency-sensitive framework that explains how working memory allocation and the automatization of lower-level linguistic processes vary across L2 readers. This review identifies key theoretical gaps and proposes directions for future research, emphasizing the need for more integrative and empirically validated accounts of reading comprehension that accommodate proficiency differences, cognitive resource dynamics, and cross-linguistic variation.

Keywords: Reading Comprehension, the Interactive Model, the Interactive-compensatory Model, the Verbal Efficiency Model, the Compensatory-encoding Model, the CC READER Model, the Multiple-processing Model.

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Introduction

Reading comprehension is a foundational skill in both first and second language development, underpinning academic achievement, professional success, and lifelong learning in increasingly text-mediated societies (Goldman & Pellegrino, 2015). In educational contexts, reading remains the primary channel through which learners access disciplinary knowledge, construct conceptual understanding, and engage with complex information across domains (Grabe & Stoller, 2019). Beyond its instructional role, reading is also a cognitively demanding activity that requires the coordination of perceptual, linguistic, and higher-order cognitive processes to construct coherent mental representations of text (Perfetti & Stafura, 2014). Given its centrality, understanding how reading comprehension operates has become a major focus of inquiry in applied linguistics, cognitive psychology, and educational research.

Despite broad consensus on its importance, reading comprehension is not a unitary or easily reducible process. Rather, it involves the dynamic interaction of multiple components, including word recognition, syntactic parsing, inferencing, background knowledge activation, and working memory regulation (Grabe & Stoller, 2019). This complexity has made it difficult to develop a single comprehensive account of how meaning is constructed from text, resulting in a rich body of theoretical work that attempts to explain different aspects of the reading process. These theories not only reflect evolving views of cognition but also respond to pedagogical concerns regarding how reading can be effectively taught and assessed in both L1 and L2 contexts.

The development of reading theories has therefore played a crucial role in shaping how comprehension is conceptualized and researched. Early models sought to isolate dominant processing directions, whereas later frameworks emphasized integration, compensation, and resource limitations in skilled reading (Mahshanian et al., 2025a). These theoretical perspectives have guided empirical research agendas, informed instructional practices, and shaped assessment approaches in language education (Bernhardt, 2010). However, the diversity of models has also led to fragmentation, with different frameworks often emphasizing distinct cognitive mechanisms without always being integrated into a unified explanatory account (Floyd et al., 2012).

In particular, existing research reveals a persistent tension between models that prioritize bottom-up linguistic decoding and those that emphasize top-down knowledge-driven interpretation (Shahnazari, 2012). Although interactive approaches have been proposed to reconcile this divide, substantial variation remains in how different theories conceptualize cognitive resources, processing constraints, and the role of proficiency in L2 reading. Moreover, recent empirical advances—especially in eye-tracking and cognitive research—have challenged simplified accounts of reading by demonstrating the importance of automatization, efficiency of lexical access, and working memory limitations in shaping comprehension outcomes (Mahshanian et al., 2025b; Perfetti, 2007).

Against this background, there remains a need for a more integrative synthesis that traces how theoretical accounts of reading have evolved and how they collectively contribute to current understandings of comprehension as a resource-dependent and proficiency-sensitive process. Specifically, there is a gap in the literature in systematically connecting earlier interactive and compensatory models with more recent capacity-based and multiple-processing frameworks in L2 reading research. Addressing this gap is important not only for theoretical coherence but also for clarifying how cognitive constraints and linguistic proficiency jointly shape reading performance.

The present review responds to this need by examining major theoretical developments in reading comprehension, beginning with unidirectional models and progressing toward interactive, compensatory, and capacity-constrained frameworks. It then situates the Multiple-Processing Account within this theoretical trajectory as an attempt to refine existing explanations of how readers allocate cognitive resources during comprehension, particularly in L2 contexts. By doing so, this review aims to provide a more coherent synthesis of competing perspectives and to highlight implications for future research and pedagogical practice in reading comprehension.

Bottom-up and Top-down Models

Given the highly complex nature of reading comprehension, which places considerable demands on multiple cognitive processes (Goldman, 2024), the reading literature has commonly distinguished between unidirectional and interactive (or multidirectional) models of comprehension. Shahnazari (2012) describes unidirectional models as viewing reading as a linear flow of information, either from the text to meaning (bottom-up) or from prior knowledge to interpretation (top-down). In the bottom-up view, comprehension is treated as a staged process in which meaning emerges only after lower-level operations such as word recognition and syntactic parsing have been completed (Stanovich, 1980). Reading is therefore seen as progressing from visual and lexical identification to syntactic processing and finally to the integration of sentence-level information into a coherent discourse representation (Shahnazari & Dabbaghi, 2014).

In contrast, the top-down perspective conceptualizes reading as an interactive, meaning-oriented process with a central role assigned to higher-level resources such as background knowledge, expectations, and activated schemas in guiding interpretation of textual input. This model was originally advanced in a study by Goodman (1967) where he cast doubts on the premises of the bottom-up approach. He proposed that readers actively draw on prior knowledge to form expectations and selectively attend to key textual information rather than fine-grained decoding of surface linguistic forms. As Cruz and Escudero (2012) note, interpretation is guided by mental representations and world knowledge, which shape both anticipatory processing and reading strategies.

Both bottom-up and top-down models have been subject to substantial critique for their conceptual limitations. The bottom-up model's emphasis on the linear and sequential decoding of textual elements is increasingly viewed as insufficient within the framework of contemporary cognitive theories (Taky-Eddine & Madaoui, 2024). The bottom-up model views reading as a strictly linear and mechanical process, where comprehension is thought to emerge solely through the sequential execution of lower-level linguistic tasks such as word recognition and syntactic parsing. However, this perspective inadequately represents the interactive and recursive processes characteristic of skilled reading. Evidence increasingly shows that proficient readers continuously integrate textual input with cognitive resources, drawing on prior knowledge, generating inferences, and adjusting predictions during reading (Grabe, 2009).

The narrow focus on decoding processes often happens at the expense of higher-order cognitive functions such as comprehension monitoring, inferencing, and schema activation (Verhoeven et al., 2011). Empirical evidence also indicates that proficient readers rely extensively on these strategic (higher-level) mechanisms to develop coherent and contextually grounded interpretations of texts (Zargar et al., 2020). By conceptualizing comprehension as the cumulative outcome of discrete linguistic decoding, the model oversimplifies reading and downplays the role of contextual information, prior knowledge, and reader expectations in meaning construction (Smith, 2012).

Similarly, the top-down model has been subject to critique due to its assumption that skilled readers primarily construct meaning through selective sampling of textual information. However, eye-tracking evidence indicates that proficient readers typically fixate on most words in a text rather than relying on limited cues (Hyönä & Kaakinen, 2019). In addition, Research has shown that eye movements in fluent reading are largely automatic and closely tied to the visual and linguistic properties of the text (Albrengues et al., 2019;

Rayner et al., 2005), which challenges the model's view of comprehension as a hypothesis-driven process. Another limitation of the top-down model is its tendency to downplay the role of lower-level decoding processes (Perfetti & Stafura, 2014). Empirical research consistently shows that fluent reading depends on the automatic recognition of words, which frees cognitive resources for higher-level interpretive activity (Mahshanian et al., 2025a; Nassaji, 2014; van Viersen et al., 2025).

These limitations highlight the inadequacy of explaining reading comprehension through strictly unidirectional frameworks. Accumulated empirical and theoretical critiques of both bottom-up and top-down models indicate that they fail to fully capture the dynamic, reciprocal, and context-dependent nature of skilled reading. Consequently, the interactive model has been proposed, emphasizing that comprehension emerges from the simultaneous interaction of bottom-up (data-driven) and top-down (knowledge-driven) processes (Kim, 2024).

The Interactive Model

The Interactive Model (Rumelhart, 1977) conceptualizes reading as a parallel and non-linear process in which comprehension emerges through the continuous interaction of top-down resources (e.g., prior knowledge and expectations) and bottom-up information (e.g., orthographic, lexical, and syntactic cues) (Kong, 2019; Tang, 2022). Central to the interactive model is the coordination between long-term memory and working memory. Visual input is initially stored in a temporary buffer before being processed in the pattern synthesizer, where diverse knowledge domains—orthographic, semantic, syntactic, and contextual—are retrieved from long-term memory to working memory (Hart et al., 2025; Macaro, 2003). When both linguistic and background knowledge are jointly activated, comprehension becomes more efficient due to continuous bidirectional interaction across processing levels (Tang, 2022; Stanovich, 1980). Accordingly, reading comprehension depends on the active processing of textual information in working memory, the retrieval of relevant prior knowledge, and the integration of these sources into a coherent representation of discourse (Cain & Oakhill, 2006; Grabe & Stoller, 2019).

Despite its theoretical significance (Lestari et al., 2023), the interactive model has also been subject to important criticism. Grabe (2009), for instance, questions the empirical validity of the model's core assumption—that higher-level processes directly influence automatic word recognition. Drawing on eye-tracking data and fluent reading behavior, he argues that word recognition is largely automatic and minimally influenced by contextual or inferential processes. In a similar vein, Alderson (2000) challenges the model's explanatory adequacy, noting that it does not fully account for several robust empirical findings in reading research.

Additional critiques arise from modular accounts of cognition. Perfetti and Hogaboam (1975), for instance, argue that lexical access operates as an autonomous process that is largely resistant to top-down influence. Their evidence highlights the rapid and independent nature of word recognition in skilled reading, thereby challenging claims of continuous interaction across processing levels. In support of this perspective, neurocognitive findings (e.g., Davis et al., 2004) indicate partially distinct neural systems for word-level processing and discourse comprehension, suggesting a degree of functional separation between these stages. Consequently, although the interactive model provides an integrative account of reading, it still requires further empirical scrutiny and refinement to fully capture the complexity of comprehension processes (Grabe, 2009).

The Interactive-Compensatory Model

It should be acknowledged that Rumelhart's (1977) interactive model represented a more comprehensive view of reading by positing the parallel use of multiple knowledge sources in reading. However, the model provides limited explanation for differences between skilled and less-skilled readers (Grabe & Stoller, 2019). To address this shortcoming, along with the limitations of earlier bottom-up and top-down perspectives, Stanovich (1980) proposed the interactive-compensatory model. While maintaining the assumption of interaction among processing levels, this model adds a compensatory mechanism, whereby weaknesses in one component, such as word recognition, can be offset by strengths in another, such as background knowledge, to support ongoing comprehension (Kosaka, 2025). Conversely, when prior knowledge is insufficient, readers rely more heavily on bottom-up textual information to derive meaning (Sevilla Morales & Méndez Pérez, 2015).

Stanovich's (1980) model rests on two core assumptions (Cruz & Escudero, 2012). First, reading comprehension results from the concurrent interaction of higher-level resources (e.g., background knowledge) and lower-level processes (e.g., lexical and syntactic decoding). Second, it operates as an adaptive system in which weaknesses in one component lead to increased reliance on others. This adaptive system enables readers of varying proficiency levels to adjust their strategies according to textual demands (Alderson, 2000; Grabe & Stoller, 2019; Stanovich, 2000). For example, when word recognition is demanding, readers may rely more on background knowledge to preserve coherence, whereas unfamiliar contexts often require greater dependence on bottom-up processing such as syntactic analysis (Gamboa-González, 2017). In this way, the model conceptualizes reading as a dynamic interaction between processing levels, with compensatory mechanisms supporting comprehension when difficulties arise.

The Interactive-Compensatory Model also tends to explain inconsistent findings in reading research, particularly the observation that less proficient readers may depend more on contextual cues than skilled readers, a pattern that conflicts with standard top-down predictions. The model addresses this issue by assuming that all sources of knowledge operate in parallel during reading. From this perspective, limitations in lower-level processing can be offset by increased reliance on higher-level contextual information. It should be noted, however, that the compensatory mechanism is not consistently active. When reading proceeds fluently and both lower- and higher-level processes function efficiently, operations such as word recognition and syntactic parsing tend to occur automatically with minimal reliance on higher-level support (Grabe, 2009; Stanovich, 2000), suggesting that the compensatory system is activated only when difficulties in lower-level processing disrupt comprehension.

A closer look at the Interactive-Compensatory Model reveals substantial overlap with other influential theories of reading comprehension. Its central claim—that "efficient low-level processing frees cognitive resources for higher-level operations" (Stanovich, 1980, p. 58)—is closely aligned with the automaticity framework proposed by LaBerge and Samuels (1974), which similarly emphasizes the role of automatized decoding in supporting higher-order processing. In addition, the model shares conceptual similarities with the limited-capacity perspective advanced by Lesgold and Perfetti (1978), as both assume that processing systems operate under constraints that limit the amount of information each level can manage at any given time.

Despite substantial empirical support (Ahsani & Budairi, 2022), the applicability of the interactive-compensatory model is constrained. Ismail et al. (2015) note that such compensatory mechanisms may not be accessible to all readers, particularly those lacking sufficient skills or strategies, while Walczyk and Griffith-Ross (2007) further suggest that compensatory processing is an acquired ability that develops through experience rather than an inherent cognitive feature. This model has also been criticized for relying on a rather simplified distinction between lower- and higher-level processes, which does not fully reflect the complex interaction of multiple cognitive mechanisms involved in reading (Bahari et al., 2024). In particular, its assumption that higher-level processes compensate for failures in lower-level processing overlooks compensatory dynamics within processing levels themselves, such as phonological decoding supporting word recognition without engaging higher-level knowledge.

Moreover, while the interactive model represented a major advance over earlier unidirectional accounts, its explanatory power remains constrained by the absence of a clearly specified mechanism governing the allocation of cognitive resources across processing levels. The model assumes continuous interaction among knowledge sources but offers limited explanation of how such interactions vary across proficiency levels or under conditions of cognitive load. From this perspective, the model appears theoretically integrative but cognitively underspecified. These limitations have encouraged the development of more comprehensive models that better capture the dynamic and multifaceted nature of reading comprehension, hence the following.

The Verbal Efficiency Model

The verbal efficiency model, originally advanced by Perfetti (1985), rests on the central assumption that although reading involves interactive processing, successful higher-level comprehension depends fundamentally on the fluency of lower-level processes, especially word recognition (Hudson, 2007; Sabatini et al., 2020). Perfetti (2007) argues that difficulties in higher-order processes such as inference generation often originate in inefficient word recognition. From this perspective, word recognition and reading fluency are treated as core components of comprehension (Silverman et al., 2013). Fluency, defined by Hannon (2012) as the rapid access to word meanings, relies on accurate and automatic recognition of written forms (Paige et al., 2014). Accordingly, fluent reading reflects both the ability to map print to spoken forms with precision (Samuels, 2006) and the capacity to recognize words effortlessly, thereby reducing cognitive load during text processing (Kuhn et al., 2010).

The model distinguishes between two main forms of processing: local processing and text-modeling (Perfetti, 1999). Local processing refers to the decoding of individual words and the construction of basic semantic propositions (Haenggi & Perfetti, 1994), typically operating in a sequential, bottom-up manner, or "one word at a time" processing (Perfetti, 2007, p. 375). Effective operation at this level is essential for establishing the basic textual foundation of comprehension. In contrast, text-modeling involves the integration of contextual information and prior knowledge with these initial representations to construct a coherent mental model of the text (Adams et al., 1995; Shahnazari & Dabbaghi, 2014). This higher-level process is responsible for inferencing, coherence formation, and the incorporation of background knowledge into overall comprehension.

Text-modeling, on the other hand, refers to the iterative process through which readers integrate contextually appropriate lexical meanings with knowledge-based inferences to construct and refine propositional representations in working memory, aligning them with prior interpretations and background knowledge to achieve a coherent mental representation of the text (Perfetti, 1985; Adams et al., 1995; Shahnazari & Dabbaghi, 2014). The efficiency of this integrative process is constrained by the limited capacity of working memory (Baddeley, 2017) and is therefore critically dependent on the automatization of lower-level processes, particularly word recognition. Within the verbal efficiency framework, rapid and accurate lexical processing reduces cognitive load and enables the allocation of attentional resources to higher-order operations such as inference generation; conversely, inefficiencies at the lexical level impose substantial processing demands that restrict the resources available for integrative comprehension, thereby undermining the construction of a coherent text representation (Grabe, 2009; Sabatini et al., 2020; Silverman et al., 2013).

In support of the verbal-efficiency model's assumption that weak reading performance stems from inadequate word-recognition abilities, Hannon (2012) draws on several studies distinguishing less-skilled and skilled readers based on their orthographic, phonological, and semantic competencies. For instance, Hannon cites Bell and Perfetti's (1994) study, which demonstrates that skilled readers outperform less-skilled readers in identifying individual words. To further shed light on the critical role of fluency and automaticity in reading, Hannon references studies by Cunningham et al. (1990) and Chabot et al. (1984), which suggest that faster word decoding leads to improved text comprehension. Although word-recognition ability shows a moderate correlation with reading comprehension ($r \approx 0.55$; Holmes, 2009) and highlights the importance of working memory in supporting higher-level processes (Hudson, 2007), the verbal-efficiency model offers limited explanation of how the contribution of working memory changes as language proficiency develops.

Recent studies have questioned the verbal-efficiency model's strong emphasis on automatic word recognition and fluency as the main determinants of reading comprehension. Mahshanian et al. (2023, 2025a, 2025b), for instance, propose a more comprehensive account in which the interaction between working memory, lower-level processes, and higher-order skills varies according to language proficiency. In Mahshanian's (2023) multiple-processing model of L2 reading, lower-proficiency learners rely heavily on working memory to support under-automatized processes such as word recognition, syntactic parsing, and semantic encoding. This increased cognitive demand limits the resources available for higher-level operations, including inference generation and information integration (Liu et al., 2019; Walczyk, 1995), resulting in slower and more effortful reading. In contrast, high-proficiency L2 readers rely more on higher-order processes, particularly comprehension monitoring (Zargar et al., 2020), which supports more efficient text processing.

Mahshanian and colleagues further contend that, for less proficient readers, comprehension depends not only on the accuracy of word recognition and semantic encoding but also on their processing speed when decoding words for their form and meaning. They also highlight the central role of syntactic parsing, challenging Perfetti's (1994) claim that efficient word recognition alone is sufficient to release cognitive resources for higher-level processing. Instead, Mahshanian et al. (2023, 2025a, 2025b) propose that reading comprehension reflects a dynamic interaction among working memory, word recognition, syntactic parsing, semantic encoding, and comprehension monitoring, with their relative contribution varying across proficiency levels. From this perspective, the verbal-efficiency model is limited in that it underrepresents individual differences in working memory capacity and the shifting allocation of cognitive resources across processing stages, pointing to the need for a more integrated account of reading comprehension.

The Compensatory-Encoding Model

While Perfetti's (1994, 2007) verbal efficiency model explains skilled reading largely through automatized lexical processing, it offers a limited account of how less proficient readers achieve comprehension despite inefficiencies in lower-level processing (Naumann & Goldhammer, 2017). To address this gap, Walczyk (1995, 2000) introduced the compensatory-encoding model, which proposes that readers can offset weak word-recognition skills through the strategic use of higher-level processes. Building on Perfetti's (1988) and Stanovich's (1980) work, this framework extends verbal efficiency theory by maintaining the importance of automaticity and working memory (Walczyk, 2000; Walczyk et al., 2001), while reconceptualizing compensation as a flexible and dynamic mechanism in reading comprehension (Grabe, 2009).

A key departure from Stanovich's (1980, 2000) sequential account lies in its treatment of compensation. Rather than viewing compensatory processes as activated only after breakdowns in lower-level processing, Walczyk conceptualizes comprehension as a continuous and adaptive activity in which readers deploy compensatory strategies across processing levels as needed (Grabe, 2009). This dynamic perspective portrays compensation not as a reactive mechanism but as a proactive effort to sustain comprehension. A further distinction lies in the role of time constraints: under untimed conditions, compensatory strategies are more likely to be employed, whereas time pressure constrains their use and shifts reliance toward lower-level decoding processes (Shahnazari & Dabbaghi, 2014). Empirical findings consistently support this distinction, showing improved comprehension when readers are given additional time (Breznitz, 2006; Breznitz & Share, 1992; Walczyk, 1995; Walczyk et al., 1999), highlighting the role of temporal flexibility in enabling compensation.

In the absence of strict time constraints, readers often rely on a combination of cognitive and metacognitive strategies to manage processing limitations. Cognitive strategies such as inferencing facilitate meaning construction, whereas metacognitive strategies—particularly monitoring and goal evaluation—support the regulation of comprehension (Kim et al., 2018; Shahnazari & Dabbaghi, 2014). Among these, lookback behavior, or revisiting earlier text segments, is especially prominent when working memory is constrained, or retrieval is inefficient (Tobia & Bonifacci, 2020). Such strategies help restore coherence and recover missing information, with empirical studies underscoring their effectiveness under cognitive strain (Franks et al., 2013; Walczyk & Taylor, 1996). Further evidence indicates that readers with lower working memory efficiency engage more frequently in lookback strategies than those with more efficient retrieval capacities (Tobia & Bonifacci, 2020). This pattern reinforces the compensatory-encoding model's emphasis on the interaction between working memory limitations and metacognitive control—particularly comprehension monitoring—in sustaining successful reading.

Despite its advances over earlier frameworks, the model offers limited specification of how lexical, syntactic, and semantic information are encoded and coordinated within working memory during comprehension. It also insufficiently addresses individual differences in working memory capacity across proficiency levels, leaving unclear how such variability shapes reading performance (Mahshanian et al., 2025a). These limitations point to the need for a more elaborated account of the dynamic interplay among working memory, strategy use, and language proficiency, as well as a clearer explanation of how working memory supports comprehension across diverse reader populations.

The Capacity Constrained Reader Model (CC READER Model)

The Capacity-Constrained Reader Model (CC READER; Just & Carpenter, 1992) is a foundational framework that explains individual differences in reading comprehension through limitations in working memory (WM) capacity (George et al., 1997). The key premise in this model is that multiple cognitive processes operate in parallel, while WM determines the extent to which information can be simultaneously activated and maintained (Woelfer et al., 2019). A central mechanism in the model is activation-based processing. Incoming textual information activates related representations in long-term memory, but only those exceeding a certain activation threshold remain available for further processing in WM (George et al., 1997). Thus, WM capacity reflects the number of activations that can be simultaneously sustained and manipulated (Miyake et al., 1994). Because individuals differ in this capacity, variability in reading performance emerges, with skilled readers typically maintaining and integrating more information efficiently than less-skilled readers (Reichle et al., 2000).

Within this framework, WM capacity also influences processing speed and accuracy. Individuals with greater capacity can maintain more concurrent activations, supporting more efficient comprehension (Hamilton et al., 2013). However, increases in linguistic complexity or ambiguity place greater demands on WM, reducing performance efficiency (Grabe, 2009). Further, Liu et al. (2019) emphasize that higher WM capacity enables simultaneous maintenance of syntactic and semantic information, facilitating more effective integration and comprehension. This parallel activation mechanism highlights WM's central role in coordinating multiple linguistic processes during reading. The model therefore conceptualizes WM as a single limited resource shared between storage and processing, requiring flexible allocation depending on task demands (George et al., 1997).

Despite its influence, the model has notable empirical limitations. Kaakinen et al. (2003), for example, contend that the model does not explain why readers with lower WM capacity show stronger perspective-related effects than those with higher capacity. That is, the model does not fully capture the complexity of context-sensitive and individual-difference effects in reading. More recently, Mahshanian et al. (2023, 2025a, 2025b) argue that WM is particularly critical for less proficient or L2 readers, who rely heavily on it for word recognition, syntactic parsing, and semantic encoding. In contrast, skilled readers depend less on WM due to greater automatization of lower-level processes. Importantly, high-proficiency readers may still achieve strong comprehension even with lower WM capacity, provided their linguistic skills are well developed. This evidence also challenges the CC READER model's linear view of WM–comprehension relationships and suggests a more proficiency-sensitive account of cognitive processing in reading. These limitations motivate the need for more integrative frameworks, such as the multiple-processing model presented in the following section.

The Multiple-Processing Model

The Multiple-Processing Model (MPM) of reading (Figure 1) is a recent framework developed and empirically supported in studies involving L2 learners (Mahshanian, 2023; Mahshanian et al., 2023, 2025a, 2025b). Extending earlier models of reading comprehension, it explains how cognitive resources are coordinated during reading, with a specific focus on differences across proficiency levels. The model emphasizes the interaction among working memory (WM), lower-level linguistic processes (i.e., word recognition, syntactic parsing, and semantic encoding), and higher-level metacognitive processes, particularly comprehension monitoring. A central claim is that low- and high-proficiency readers follow distinct cognitive pathways to achieve comprehension, thereby extending and refining capacity- and compensation-based accounts such as Just and Carpenter's (1992) CC READER model and Walczyk's (1995) compensatory-encoding framework.

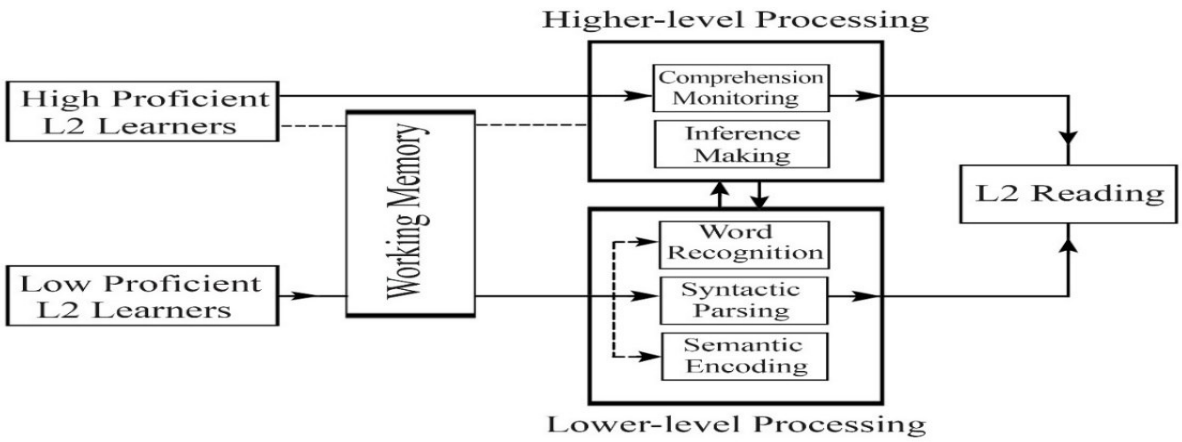

Figure 1. The Multiple-Processing Model of L2 Reading

Mahshanian's multiple-processing model emerged from convergent findings across diverse methodologies, including eye-tracking and timed versus untimed reading assessments, involving L1-Persian EFL learners. The research demonstrated that less proficient readers heavily depend on WM resources to compensate for their incomplete automatization of lower-level processes—particularly semantic encoding and syntactic parsing—thereby constraining the cognitive capacity available for higher-order integrative tasks (Mahshanian et al., 2025a, 2025b). Conversely, advanced L2 readers exhibit greater automatization in these lower-level processes, enabling them to allocate WM more efficiently towards strategic comprehension monitoring and inferential processing (Mahshanian et al., 2023). This bifurcation underscores that proficiency modulates the cognitive architecture of L2 reading, where WM's role is not uniform but mediated by the automatization of lower-level skills and the strategic deployment of higher-level processes.

The empirical foundation of the MPM derives from multiple methodological approaches, including eye-tracking and comparisons of timed versus untimed reading tasks with L1-Persian EFL learners. Findings indicate that less-proficient readers rely heavily on WM to support under-automatized lower-level processes, particularly syntactic parsing and semantic encoding. This reliance limits the resources available for higher-order integration and inference generation (Mahshanian et al., 2025a, 2025b). In contrast, more advanced readers show greater automatization of these processes, allowing WM resources to be allocated more efficiently to comprehension monitoring and inferential processing (Mahshanian et al., 2023). This pattern suggests that proficiency fundamentally reshapes the cognitive architecture of reading by moderating the balance between automatic and controlled processing. In this sense, the model aligns conceptually with capacity- and compensation-based approaches, such as Walczyk's (1995) Compensatory-Encoding Model and Just and Carpenter's (1992) Capacity-Constrained Reader Model, while extending them to a proficiency-sensitive context.

The model further advances earlier frameworks by explicitly incorporating the role of time pressure in reading performance, a factor noted in Walczyk's compensatory-encoding model but not fully explored in the capacity-constrained reader model. A key contribution of the MPM is its systematic focus on temporal constraints. Under untimed conditions, less-proficient readers can partially offset weaknesses in decoding and parsing through compensatory strategies. However, time pressure increases working memory load and consequently reduces comprehension accuracy (Mahshanian et al., 2025a). In this way, the model extends prior accounts by clarifying how processing speed and cognitive resource allocation jointly shape reading performance across proficiency levels.

Despite its theoretical and empirical contributions, the MPM presents several challenges warranting further investigations on several fronts. First, the model is explicitly designed for L2 reading contexts, and its premises may not translate fully to L1 reading. L1 readers typically possess a substantially larger vocabulary (Bosch et al., 2020) and exhibit near-automatic syntactic processing, which considerably reduces cognitive load and frees WM resources for higher-level comprehension (Mahshanian et al., 2025b). This distinction raises questions about the extent to which the model's emphasis on WM constraints and lower-level processing deficits applies beyond L2 contexts, where automatization is more pervasive (Mahshanian et al., 2025b).

Second, the empirical base for the MPM stems primarily from research on Iranian learners whose L1 is Persian (Farsi), characterized by orthographic features markedly different from English—such as right-to-left script direction and a consonantal writing system—contrasting with English's left-to-right alphabetic orthography. This orthographic distance may exacerbate the cognitive demands of L2 reading for these learners relative to those whose L1 orthographies are closer to English (Koda, 1988). Consequently, the generalizability of the model across diverse L1 backgrounds remains an open empirical question, given that orthographic transparency and similarity impact processing ease and WM load during reading.

To recap, the multiple-processing model represents a significant advancement in reading research by incorporating proficiency-sensitive, temporally informed, and cognitive resource-centered perspectives into the understanding of L2 reading comprehension. Grounded in empirical evidence, it challenges the universality of prior models and invites a more differentiated conceptualization of how WM, lower-level linguistic processing, and metacognitive monitoring collaboratively shape L2 reading outcomes. Nevertheless, its full validation and refinement hinge on addressing the outlined challenges, particularly through cross-linguistic research and investigations into intra-individual compensatory mechanisms within low-proficiency readers.

Conclusion

The evolution of reading comprehension models reflects a sustained theoretical effort to explain how readers construct meaning from written text through the interaction of linguistic processing, cognitive resources, and background knowledge. Early frameworks such as the Interactive and Interactive-Compensatory Models emphasized the integration of bottom-up and top-down processes, whereas the Verbal Efficiency Model highlighted the centrality of automatized lower-level processing in supporting fluent comprehension. Subsequent accounts, including the Compensatory-Encoding and Capacity-Constrained Reader (CC READER) models, extended this trajectory by incorporating flexibility in strategic processing and by foregrounding the role of working memory constraints in explaining individual differences in reading performance.

Despite these advances, several important research gaps remain. First, existing models differ substantially in how they conceptualize the dynamic allocation of working memory across processing levels, particularly under varying proficiency conditions. Most frameworks either treat working memory as a stable capacity constraint or assume relatively fixed interactions between lower- and higher-level processes, leaving limited explanation of how resource allocation changes as readers develop proficiency. Second, current models provide insufficient integration of processing speed and automatization with strategic metacognitive control, despite growing evidence that these dimensions jointly shape comprehension outcomes. Third, much of the empirical base underpinning major reading models derives from relatively homogeneous participant populations, limiting the generalizability of theoretical claims across linguistic backgrounds, orthographic systems, and L1–L2 contexts.

Building on these limitations, recent proposals such as the Multiple-Processing Model (MPM) (Mahshanian, 2023; Mahshanian et al., 2023, 2025a, 2025b) offer a more differentiated account of reading by distinguishing cognitive pathways across proficiency levels and explicitly modeling the interaction among working memory, lower-level linguistic processing, and metacognitive monitoring. While the MPM advances the field by integrating automatization, resource allocation, and time pressure effects, it also raises new empirical questions regarding its cross-linguistic validity and its applicability beyond the specific L2 populations in which it has been tested.

Future research should therefore pursue at least three complementary directions. First, cross-linguistic and cross-orthographic investigations are needed to determine whether the proposed proficiency-sensitive pathways generalize across learners with different L1 backgrounds and writing systems. Second, multi-method studies combining eye-tracking, behavioral, and neurocognitive measures are required to more precisely capture how working memory supports the coordination of lexical, syntactic, and discourse-level processing in real time. Third, longitudinal designs would be particularly valuable in examining how automatization and compensatory strategies evolve as readers transition from lower to higher proficiency levels, thereby clarifying whether changes in processing architecture are gradual, threshold-based, or context-dependent.

Taken together, the reviewed models illustrate a progressive shift toward increasingly integrative accounts of reading comprehension that emphasize the interaction of cognitive resources, linguistic processing efficiency, and reader proficiency. Continued empirical work addressing the gaps outlined above is essential for refining current theoretical frameworks and moving toward a more comprehensive, generalizable model of reading comprehension across contexts and populations.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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