Reading Comprehension

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Summary and Keywords

Reading comprehension requires the construction of a coherent mental representation of the information in a text. Reading involves three interrelated elements—the reader, the text, and the activity, all situated into a broader sociocultural context. The complexity inherent in reading comprehension has given rise to a multitude of influential models and frameworks that attempt to account for the various *processes* that give rise to reading comprehension: for example, activation of prior knowledge and integration of incoming information with currently active memory contents. Other models and frameworks attempt to account for the *components* that constitute reading comprehension, such as decoding, vocabulary, and language comprehension.

Many of the most prominent models of reading comprehension describe single readers engaging with single texts. Several recent models attempt to account for the additional complexity of comprehending multiple texts. Along with engaging in comprehension of multiple texts comes the need to contend with multiple information sources (i.e., sourcing). As such, researchers have developed models and frameworks to capture the processes learners engage in when the need to engage in sourcing arises, such as when readers encounter conflicting information.

Much theorizing in the reading comprehension literature has implicated typical readers, which suggests that many models and frameworks may not represent all readers across various skill levels. Existing research has identified several sources of individual differences in reading comprehension that in part determine the success of comprehension processes. Such individual differences include working memory, executive functions, vocabulary, inferencing, and prior knowledge. Prior knowledge is particularly important because of its power to both facilitate and interfere with comprehension processes. As such, the need to overcome the disruptive influence of incorrect prior knowledge (i.e., knowledge revision) becomes especially important when readers encounter information that conflicts with that prior knowledge.

Keywords: Reading comprehension, individual differences, sourcing, multiple-text comprehension, knowledge revision

Introduction

The aim of this article is twofold. First, it provides a general overview of reading comprehension by outlining classic models of single-text comprehension and more recent models of multiple-text comprehension and sourcing during reading comprehension. Second, the article highlights important sources of individual differences in reading comprehension with a particular focus on identifying sources of comprehension difficulty. The article concludes with open questions and potential future directions.

What is Reading Comprehension?

What does it mean to read and understand a text? Central to any conceptualization of reading comprehension is that it requires the construction of a mental representation of the information in a text (Kintsch, 1988). More formally, reading comprehension has been defined as "the process of simultaneously extracting and constructing meaning through interaction and involvement with written language" (Snow, 2002, p. 11). Reading involves three interrelated elements: the reader, the text, and the activity or reading task, all situated into a broader sociocultural context. To comprehend a text, a reader must be equipped with a host of abilities (e.g., attention, memory, inferencing), motivation (e.g., reading goals, interest) and knowledge (e.g., domain knowledge, linguistic knowledge), all of which are influenced by the specific texts used and the activity the reader is engaging in (Snow, 2002). Although each of these elements is important for reading comprehension, in this article, we emphasize reading processes, components, and individual differences.

Reading comprehension is considered one of the most complex activities humans can perform (Kendeou, McMaster, & Christ, 2016). This complexity hinders the development of a comprehensive theory that can make precise predictions across readers, texts, and discourse contexts (Kendeou & O'Brien, 2014; Perfetti & Stafura, 2014). Consequently, researchers have put forth models that focus on a limited set of components and processes of reading comprehension. Next, we will describe process models, followed by components models.

Overview of Models and Theories of Reading Comprehension

Prominent Process Accounts

"Process models" of reading comprehension aim to identify the various processes, linguistic and cognitive, necessary to construct a mental representation during reading (McNamara & Magliano, 2009). Prominent among these models are the construction-integration model (Kintsch, 1988), the landscape model (Van den Broek, Young, Tzeng, & Linderholm, 1999), the event-indexing model (Zwaan, Langston, & Graesser, 1995), the resonance model (Myers & O'Brien, 1998), the constructionist theory (Graesser, Singer, & Trabasso, 1994), and the structure building framework (Gernsbacher, 1991).

The construction-integration (CI) model (Kintsch, 1988) is one of the most influential models and a good approximation to a theory of reading comprehension (Kendeou & O'Brien, 2018; McNamara & Magliano, 2009). According to the CI model, comprehension is the result of two core processes: construction and integration. *Construction* refers to the activation of information from the text and prior knowledge that resides in the reader's memory. Activated information can come from four different sources: the current text input, the prior sentence, background knowledge, and recently read text. As this information is reactivated, it becomes integrated into an interconnected network of concepts. *Integration* refers to the continuous spread of activation throughout this network until activation settles. After spreading activation settles, those concepts connected to many others are maintained in the network, whereas concepts that are less connected decay in activation and drop out of the network. Construction and integration processes operate within three layers of discourse: *surface code, textbase*, and *situation model*. The surface code is the actual words within a text; the textbase consists of propositions that represent the meaning of information in the text; the situation model represents all inferences that go beyond the propositions in the textbase (McNamara & Magliano, 2009). At the completion of reading, the reader's situation model is the mental representation of what the text is about (e.g., Kintsch, 1988).

The landscape model (van den Broek et al., 1999) captures the fluctuation of concept activation as reading comprehension unfolds. The landscape model is similar to the CI model in that it assumes the same four sources of activation in every reading cycle (typically a sentence). The landscape model includes two important mechanisms that determine fluctuations in activation among concepts over time, *cohort activation* and *coherence-based retrieval*. Cohort activation assumes that when a concept is activated, all other concepts that are also activated become associated with it (McClelland & Rumelhart, 1985). Coherence-based retrieval assumes that the activation of text elements is in accordance with the readers' standards of coherence. Standards of coherence refer to explicit or implicit criteria for comprehension the reader employs and aims to satisfy during reading (Van den Broek, Bohn-Gettler, Kendeou, Carlson, & White, 2011).

The event-indexing model (Zwaan et al., 1995) aims to account for the processes involved in constructing a situation model during narrative comprehension. The model assumes that as reading unfolds, readers concurrently monitor and establish coherence along five dimensions of continuity represented as components in the situation model: the agents in the narrative, time (i.e., *when* events in the narrative occur), space (i.e., *where* events in the narrative occur), causality (i.e., *what* causes events in the narrative to occur), and motivation (i.e., *what* compels agents in the narrative to take action). These elements are represented within both the *complete model* (i.e., the result after each reading episode has completed) and the *integrated model* (i.e., the overall model that the reader constructs after all textual input has been processed across all reading episodes). The complete model that results from each reading episode is mapped onto the integrated model depending on continuity of time, space, causality, motivation, and agents. When mapping is successful, the result is a rich and multidimensional situation model of the narrative.

The constructionist theory (Graesser et al., 1994) attempts to account for factors that predict inference generation during reading. The theory emphasizes the role of top-down, strategic processes in the construction of meaning (what has been termed “search after meaning”) in which readers search working memory or long-term memory for information to maintain coherence. Three assumptions underlie search after meaning. The first is the *reader goal assumption*, which assumes that readers construct meaning in accordance with their reading goals. The second is the *coherence assumption*, which proposes that readers construct meaning at both local and global levels during reading. The third is the *explanation assumption*, which suggests that readers are driven to construct meaning that explains events they read.

The resonance model (Myers & O’Brien, 1998) outlines the factors that influence the activation of information during reading comprehension. The model emphasizes the role of automatic, memory-based retrieval mechanisms and incorporates their fundamental assumptions. Specifically, the resonance model assumes that information currently active in working memory serves as a signal to all of memory, which activates information that *resonates* with the signal. Elements resonate as a function of featural overlap; that is, the number of features that overlap with the contents of working memory. Elements that resonate strongly are drawn back into working memory where they can influence processing of incoming information.

The structure-building framework (Gernsbacher, 1991) describes comprehension as the result of three core processes. The first process, *laying a foundation*, entails using initial information from a text to establish the basis for a mental representation to be subsequently constructed. The second process, *mapping*, involves mapping incoming information from the text onto that foundation to create information “structures.” The third process, *shifting*, occurs when readers are unable to map incoming information onto a structure that is currently being constructed. In such a case, the reader may “shift” to begin building a new structure of information or modify an existing structure. Within the structure-building framework, a suppression mechanism attempts to account for individual differences in comprehension ability. Specifically, the framework proposes that if incoming information is related to the current structure, then activation of that information is *enhanced*, resulting in its incorporation into the current structure. When information is not related to the current structure, then activation to that information is *suppressed*, or, alternatively, readers may *shift* and use that information to begin building a new structure.

Prominent Component Accounts

Researchers have also developed models and frameworks to specify the linguistic and cognitive skills that underlie reading comprehension. Such work has identified several key components, including prior knowledge (Kintsch, 1988), decoding (Ehri, 2014), language comprehension (Kendeou et al., 2009) vocabulary (Quinn, Wagner, Petscher, & Lopez, 2015), oral reading fluency (Fuchs et al., 2001), and executive functions (Sesma, Mahone, Levine, Eason, & Cutting, 2009). Prominent component accounts include the simple view of reading (SVR; Hoover & Gough, 1990), the direct and inferential mediation (DIME) model (Cromley & Azevedo, 2007), and the reading systems framework (Perfetti & Stafura, 2014). The latter may be considered a "hybrid" model as we explain next.

The simple view of reading (SVR; Hoover & Gough, 1990) conceptualizes reading comprehension as the product of decoding and listening comprehension. Decoding is the process of translating print to words, whereas listening comprehension is the understanding of the meaning of spoken language. The decoding component requires multiple processes, including awareness of letter sounds (i.e., phonological awareness), awareness of spelling and combining letters (i.e., orthographic knowledge), awareness of word forms (i.e., morphological awareness), and automatization of responses to visual stimuli (i.e., rapid automatized naming). The listening comprehension component consists of several processes, including parsing, bridging, and discourse understanding (Hoover & Gough, 1990). It also draws on a host of cognitive skills and abilities, including working memory, inhibitory control, attentional control, vocabulary, grammatical knowledge, inference, perspective taking, and comprehension monitoring (Kim, 2017). An important specification of the SVR is that reading comprehension is the *product* of language comprehension and decoding, rather than the *sum* of these two components. Thus, an increase or decrease in one component depends on the level of the other component in terms of influencing reading comprehension ability. Furthermore, the absence of either component reduces reading comprehension to zero, highlighting the necessity of both component skills for reading comprehension to exist.

The direct and inferential mediation (DIME) model proposes a set of relations among five key predictors of reading comprehension: prior knowledge, inferencing, reading strategy use, word reading ability, and vocabulary (see Cromley, 2005, for a review; Cromley & Azevedo, 2007). Cromley and Azevedo found that, together, these five predictors made significant contributions to ninth graders' reading comprehension either directly and/or mediated by reading strategies and inferencing. In total, these relations accounted for 66% of the variance in reading comprehension. Cromley and Azevedo found that vocabulary and prior knowledge make the largest direct contributions to reading comprehension followed by inferencing, word reading, and reading strategies. Vocabulary and prior knowledge have a large direct contribution to reading comprehension, particularly when texts require a literal understanding. However, vocabulary and prior knowledge also have an indirect influence via inference making when the texts had higher inferencing demands. In addition, reading strategies primarily impact comprehension when the text places higher demands on inferencing.

The reading systems framework (Perfetti & Stafura, 2014) emphasizes the importance of word knowledge in comprehension and provides an account for how words are integrated into a reader's understanding of a text. Thus, the framework centralizes the role of the reader's lexicon (i.e., knowledge about words and their uses; Perfetti & Stafura, 2014), which is generally neglected in reading comprehension research. Particularly, there are three knowledge sources used during reading—linguistic, orthographic, and general knowledge. The framework proposes that the processes of reading (i.e., decoding, word identification, retrieval, syntactic parsing, inference making, and comprehension monitoring) draw upon these knowledge sources in constrained (i.e., not all processes draw from all knowledge sources) and interactive ways (i.e., some processes draw from multiple knowledge sources). Importantly, these processes are all situated within a limited-resource system that connects perceptual and long-term memory. Given the dual focus of the framework on components and processes, one could consider it a “hybrid model.”

Comprehension From Single Texts to Multiple Texts

The dramatic changes brought on by the “information age” have posed a challenge for traditional models of reading comprehension and called for a more generalized theory of multiple-text processing (Britt & Rouet, 2012; Perfetti, Rouet, & Britt, 1999; Rouet, 2006). In response, researchers have developed several models that account for the processes involved when readers engage with multiple texts and/or multiple sources. These models include the documents model framework (DMF; Perfetti et al., 1999) and the reading as problem-solving model (RESOLV; Rouet, Britt, & Durik, 2017).

The documents model framework (DMF) (Perfetti et al., 1999) was developed to outline the mental representations and processes that underlie comprehension of multiple documents. The DMF posits that when readers engage with multiple texts, the result is a documents model. The documents model consists of two connected components or levels. The first is the intertext model, which captures readers’ representations of what each information source says and how each source relates to the others. The intertext model assumes that readers construct a “document node,” or representation of the features of every information source in the document set. These nodes are assumed to have “intertext links” with other document nodes and to have “slots” available for source information and text content. Slots can contain information regarding the author, setting, and rhetorical goals. Readers may form “source-source links” and “content-content links” as part of their intertext model. Such intertext links permit the reader to create a coherent and integrated representation of conflicting information by allowing the reader to attribute conflicting information to different sources. By contrast, if readers do not represent source information, they may form a “mush” model (Britt, Perfetti, Sandak, & Rouet, 1999) in which information is simply added to a representation without regard for who said what, in which case there are no intertext links.

The second component of the documents model is the situations model or integrated mental model, which represents the relations among semantic content found within multiple documents. Depending on the information available in the documents, readers may form a single coherent mental representation of the situations described in several documents. However, a reader may also construct *multiple* situation models, particularly when multiple documents present the same situations. Parts of the situations model can be connected to the intertext model; these connections can include different sources' conflicting accounts of the same events or corroboration among sources. When these connections are established, the result is a rich documents model that accounts for multiple accounts from multiple sources. Importantly, any factor that influences the outcome of single-document comprehension will similarly influence multiple-document comprehension. The success of the constructed documents model ultimately depends on a reader's goals, task demands, expertise, and knowledge of sources (Perfetti et al., 1999).

The RESOLV model (Rouet et al., 2017) emphasizes the reading context as essential for purposeful reading. According to the RESOLV model, readers construct two mental models at the outset of any reading activity. The first is the *context model* of the physical and/or social context in which the reading task is situated. For example, a context model may represent the information that a student in a biology class receives from his or her instructor to read a passage in order to prepare for a comprehensive exam. Thus, the person completing the task (self), the request (to read a passage), the requester (the instructor), the audience (the instructor), and any support or obstacles available are relevant features of the context model. Context models are relatively stable and encompass a reader's understanding of a reading task, but they are amenable to updating on the basis of activity outcomes and feedback. Context models can be constructed via feature extraction, pattern matching, and activation of preexisting schemata related to the context. Based on the context model, a reader constructs the *task model*, which represents the ultimate goal for engaging in a reading activity and the means by which a reader may achieve that goal. The reading activity consists of processes, decisions, and actions that result from a cost-benefit analysis regarding a reader's goals. The reader uses outcomes from the reading activity to engage in self-regulation processes that are in sync with "feeling of knowing evaluations" (i.e., a self-assessment of one's knowledge about a question or topic) and cost-benefit analysis.

Sourcing in Reading Comprehension

Although it is generally assumed that the content of a text is what matters most (Bråten, Strømsø, & Britt, 2009), the source of that content is also a factor that can influence reading comprehension. *Sourcing* captures the processes of attending to, evaluating, and using available information about the sources of documents. A *source* is an information resource, which can include the authors of a document, the document itself, and sources embedded within the document (e.g., Bråten et al., 2009). Sourcing is especially crucial and challenging when learning about controversial socio-scientific issues in which there is much disagreement (Barzilai, Tzadok, & Eshet-Alkalai, 2015). One of the key features of a source is its credibility. *Source credibility* refers to the extent to which readers perceive a source to be believable, and it is often operationalized as a source's trustworthiness and expertise (Lombardi, Seyranian, & Sinatra, 2014; Sparks & Rapp, 2011). Credibility is among the most important information readers attend to and use as they engage in sourcing, and it influences both source levels—the author of the text and the text itself

(Van Boekel, Lassonde, O'Brien, & Kendeou, 2017). Indeed, existing research has shown that readers who attend to such source information demonstrate better comprehension of texts than those who do not (Strømsø, Bråten, & Britt, 2010). However, readers do not spontaneously attend to or use source information when evaluating texts (Kobayashi, 2014).

The documents model framework (DMF) of multiple-document comprehension (Perfetti et al., 1999) is the most prominent reading comprehension model that incorporates sourcing. Additional models include the content-source integration model (Stadtler & Bromme, 2014), the discrepancy-induced source comprehension model (D-ISC; Braasch & Bråten, 2017; Braasch et al., 2012), and the source monitoring framework (SMF; Johnson, Hashtroudi, & Lindsay, 1993).

The content-source integration (CSI) model (Stadtler & Bromme, 2014) was developed to account for the processes and resources readers engage with when they encounter conflicting information about a particular issue. The model articulates three steps: *conflict detection, conflict regulation*, and *conflict resolution*. Detecting a conflict is the result of the conflicting information being coactivated. Once a conflict has been detected, an inhibitory link is established between the two conflicting information units. Conflict regulation can be achieved by ignoring the conflict, reconciling conflicting propositions (by generating explanatory inferences about the content or the sources), or by "tagging" the conflict with different sources, effectively distinguishing content rather than integrating it. In resolving a conflict, readers must develop a personal stance on the conflicting issue by engaging in firsthand (i.e., asking *what is true)* or secondhand evaluation (i.e., asking *whom to believe*). Thus, firsthand evaluation implicates the *content*, whereas secondhand evaluation implicates the *source*. Stadtler and Bromme acknowledged that the CSI model is in accord with and extends the explanatory power of the DMF model, as the DMF does not account for the processes readers engage in to *resolve* conflicts when documents present different perspectives on an issue.

The discrepancy-induced source comprehension model (D-ISC; Braasch & Braten, 2017; Braasch et al., 2012) proposes a set of processes that unfold during reading of conflicting messages presented by multiple information sources. These conflicting messages can occur across multiple documents or within a single document. D-ISC assumes many of the same processes in prominent models of text processing (Kintsch, 1988; Myers & O'Brien, 1998), in which information is passively reactivated from memory. Thus, when readers encounter inconsistent information, related information is likely to be reactivated. After discrepant information is reactivated, a more effortful processing phase takes over in which readers strategically attend to and evaluate source information in an effort to construct document nodes and include them in their mental representation. In this way, readers may restore coherence by attributing a discrepancy to different perspectives or sources rather than to an unresolvable coherence break.

The source monitoring framework (SMF; Johnson et al., 1993) broadly accounts for the processes individuals engage in when attributing memories, knowledge, or beliefs to some origin after encoding. The SMF draws from the multiple-entry module (MEM) model of memory (Johnson & Hirst, 1993). Briefly, the MEM model specifies that experiences are attributed to a particular source. These experiences do not contain abstract tags that link them to a source, but rather aspects of source are inferred, typically rapidly and automatically, on the basis of perceptual, semantic, and affective qualities of memory contents that become reactivated. According to the SMF, in the context of multiple text processing, a reader might engage in source monitoring during information retrieval in order to recall, for example, which author made a particular claim. This attribution would be based on any semantic information related to that claim that becomes reactivated during retrieval processes. Thus, the SMF accounts for the attributions learners make based on reactivated memory traces. Although the SMF assumes that we often identify the source of a memory in the course of retrieving that memory without any awareness, sometimes source monitoring involves strategic processes, such as searching for supporting memories or contextual information needed to attribute information to a source.

Individual Differences in Reading Comprehension

Most accounts of reading comprehension capture reading as it unfolds for the average typical reader. However, readers vary in skill, and there are several sources of individual differences that can influence comprehension. One cognitive factor consistently identified as an important individual difference is working memory (WM; Cain, Oakhill, & Bryant, 2004; Daneman & Carpenter, 1980). Most existing research about the relation of WM to comprehension endorses (at least implicitly) the multicomponent model proposed by Baddeley (2000), which implicates both storage and processing of information. Overall, WM can be seen as a limited processing resource that influences readers’ ability to engage in many of the processes necessary for constructing a mental representation of a text (Cain et al., 2004). WM influences reading comprehension because readers must continuously attempt to integrate incoming textual information as they read with prior knowledge or with previously read information. As processing demands increase, the resources available to keep information active in WM decrease. If the processing demands of the reading task exceed resource limitations, then loss of information and/or impaired processing will occur (Van Dyke, Johns, & Kukona, 2014). Thus, for struggling readers, oftentimes too much processing must be devoted to word identification, which precludes engagement in the comprehension processes necessary to construct meaning from text.

Another relevant cognitive ability that may similarly rely on processing efficiency is rapid automatized naming (RAN). RAN is an indicator of the ability to automatically retrieve and verbalize the names of stimuli, often colors, numbers, or letters, as quickly and accurately as possible (Denckla & Cutting, 1999). Interestingly, it is not clear precisely what RAN tasks measure, and there are several hypotheses for the relation between RAN and reading processes. First, RAN may be a component of phonological processing and thus may indirectly contribute to comprehension via word reading. Second, RAN and phonological processing may be independent contributors to reading skill (i.e., double-deficit hypothesis, Wolf & Bowers, 1999). Third, RAN and reading may be linked due to their shared dependence on general processing speed (Christopher et al., 2012; Cutting & Denckla, 2001). In any case, there is evidence that individual differences in RAN predict comprehension for school-aged readers (Li et al., 2009). One potential reason is that variability in RAN may reflect inefficiency with allocating attention during tasks that demand effortful cognitive control, which may explain its status as a significant predictor of reading comprehension (Stuebing et al., 2015).

Another set of factors emerging as potentially important for individual differences in comprehension is executive functions (EFs; Butterfuss & Kendeou, 2018). EFs are general-purpose mechanisms that manage cognition. EF consists of at least three core components: the first is working memory updating; the second is inhibition of prepotent responses or the ability to override a dominant response; the third is shifting attention or flexibly in allocating attentional resources to suit various situations (Miyake et al., 2000). Individual differences in updating contribute to reading comprehension. Specifically, struggling readers have been shown to be less efficient at updating WM contents compared to skilled readers, and consequently, are less efficient at maintaining relevant information in WM (Palladino, Cornoldi, De Beni, & Pazzaglia, 2001). Likewise, inhibition has been shown to operate on WM contents. For example, Chiappe, Hasher, and Siegel (2000) reported that both children and adults with poor comprehension struggled to keep irrelevant information from entering WM and to inhibit already active information when it became irrelevant. Thus, inhibition may serve as a gatekeeper to WM by restricting access of irrelevant information and inhibiting no-longer-relevant information. That said, Christopher et al. (2012) found that inhibition had no unique prediction for children's and adolescents' reading comprehension, perhaps because inhibition was subsumed by other factors (e.g., IQ). There is less evidence for the role of shifting in reading comprehension. However, Kieffer, Vukovic, and Berry (2013) found that shifting predicted fourth-grade students' reading comprehension. The authors speculated that shifting supports students' effective attention allocation in the face of syntactic or semantic ambiguity during comprehension.

Overall, Cutting et al. (2009) and Sesma et al. (2009) have reported compelling evidence for the role of general EF in reading comprehension. Moreover, Eason et al. (2012) found that EF contributed to reading comprehension to a greater extent for more complex reading materials (*expository* versus narrative texts) and more difficult question types (*inferential* versus literal). There is also recent speculation that EF may be the "missing ingredient" that facilitates the integration of decoding and listening comprehension (as conceptualized in the SVR model). Thus, struggling readers may actually have deficits in these *integrative* processes and not in the component processes themselves (Aboud et al., 2016).

Perhaps the most critical source of individual differences in comprehension is inferencing (Cain et al., 2001). Generally, inferencing allows readers to form connections among text elements and with prior knowledge (Graesser et al., 1994; Oakhill, Cain, & Bryant, 2003). To make an inference, readers must maintain the activation of text-derived information and must possess background knowledge from which an inference can be drawn (Cain et al., 2001; Kendeou, 2015). Children who have comprehension difficulties, despite intact word-level reading abilities, struggle to make inferences needed for maintaining global coherence; however, these children are able to make inferences needed for maintaining local coherence (Cain & Oakhill, 1999). Indeed, Cain et al. (2001) found that children with comprehension deficits were poorer at making inferences that required integration of textual information with prior knowledge. The authors posited that struggling comprehenders' difficulty may lie in an inability to select only the relevant information from a wealth of reactivated contents.

Inferencing may also be important for other higher-level abilities. For example, inferencing was found to be closely related to development of theory of mind, which involves inferring the mental and emotional states of others (Kim, 2015). Different reading scenarios also place different demands on inferencing. For example, inferences were shown to be difficult and resource intensive for expository texts but relatively automatic for narrative texts (Eason et al., 2012). Expository texts have greater structural complexity, information density, and knowledge demands (Best, Floyd, & McNamara, 2008), all of which require greater WM resources. Indeed, Cain et al. (2004) emphasized that WM efficiency is necessary, but not sufficient, for inferencing. Interestingly, poor inferencing may actually be a manifestation of lower-level cognitive problems like inefficient WM (Perfetti, Stafura, & Adlof, 2013).

Another important source of individual differences is readers' prior knowledge. In the context of reading comprehension, it is useful to think of knowledge as being represented in the form of interconnected webs of information or *semantic networks* (Collins & Quillian, 1969). One important property of prior knowledge is that it can both facilitate and interfere with reading comprehension (Kendeou & O'Brien, 2015). One way in which prior knowledge can facilitate comprehension is by providing a structure into which incoming information can be interpreted and integrated. Namely, readers tend to understand new information according to their preexisting knowledge structures in memory (i.e., schemas and scripts; Anderson & Pichert, 1978; Bransford & Johnson, 1972). Importantly, these knowledge structures interact with different kinds of texts (Kintsch, 1988; Kintsch & van Dijk, 1978). For example, both the quality and quantity of prior knowledge have been shown to influence the time it takes to process a text, construct a mental representation of the text, and generate inferences during reading (e.g., Bower & Morrow, 1990; Just & Carpenter, 1980; McKoon & Ratcliff, 1992), with specific inferences often constructed on the basis of readers' prior knowledge for the topics mentioned in texts (Graesser & Bertus, 1998; McNamara & Kintsch, 1996; Millis & Graesser, 1994; Millis, Morgan, & Graesser, 1990). When these inferences are accurate, they result in a deeper understanding of the text and a richer representation in a reader's memory. It is this rich representation that is subsequently accessed and utilized to answer questions, solve problems, or transfer to new contexts. In terms of individual differences in prior knowledge, experts (i.e., those with a large amount of high-quality knowledge in a domain) excel in recalling and using information from their domain of expertise compared to novices

(Chi, Feltovich, & Glaser, 1981), who lack a rich semantic network of domain-relevant knowledge.

Prior knowledge can interfere with comprehension when that knowledge is misconceived, incomplete, or inaccurate (Carey, 2009; Chi, 2005; Rapp, 2008; van den Broek, 2010; Vosniadou & Brewer, 1994). Indeed, there is evidence that that incorrect prior knowledge influences the actual cognitive processes, as well as the content of those processes (Kendeou, Muis, & Fulton, 2011; Kendeou & van den Broek, 2005, 2007). Specifically, readers with misconceptions process texts at the same rate and engage in the same general types of processes as readers with accurate knowledge. However, when readers with misconceptions reactivate and integrate their incorrect prior knowledge with the incoming information from the text, the inferences they generate are also incorrect. The problem is compounded because readers will continue to integrate incoming information into a flawed representation. This highlights the need for an understanding of the processes and mechanisms that readers must engage in to overcome the continued influence of their inaccurate prior knowledge during reading.

One way this can happen is by achieving a reduction in the activation of the misconception relative to the correct idea—the end result of this process is *knowledge revision*. One framework that captures the assumptions, conditions, and mechanism of knowledge revision as it unfolds during reading is *the Knowledge Revision Components Framework* (KReC; Kendeou & O'Brien, 2014). KReC has been established and examined primarily within the context of texts that are designed to promote change in misconceived knowledge by stating misconceptions, refuting them, and providing a causal explanation of the correct idea (i.e., refutation texts; Tippett, 2010).

The KReC framework comprises five principles that help explain knowledge revision while reading refutation texts. The first principle (*the encoding principle*) assumes that information that is encoded and stored into long-term memory always has the potential to be re-activated and therefore become part of the discourse model as comprehension unfolds. This is the case because information that is encoded and stored cannot simply be erased or replaced. The second principle (*the passive activation principle*) assumes that prior knowledge (e.g., a misconception) can be reactivated via passive memory-based processes. Reactivation of prior knowledge can occur regardless of whether it is relevant or correct. Therefore, it is possible that information from the text may reactivate a misconception, which can then be incorporated into the reader's current mental representation. The third principle (*coactivation*) is the means by which the new information meets the misconception—this is a direct product from the first two assumptions (the encoding and passive activation principles). Once a connection is established between the misconception and newly encoded information, the new information can become integrated with the misconception (*integration principle*). The fifth principle (*competing activation principle*) provides the mechanism by which the misconception can be reduced in activation. Particularly, as readers encode more elaboration supporting the newly encoded correct information, activation is drawn to that information, concurrently drawing activation away from the misconception (due to a system of limited resources).

Thus, KReC posits competing activation as the core revision mechanism. Specifically, when textual information is strengthened in memory (for example by using elaborate descriptions or explanations), it has the potential to dominate and eliminate measurable disruption caused by the misconceptions (Kendeou, Butterfuss, Kim, & Van Boekel, 2019; Kendeou & O'Brien, 2014; Kendeou, Smith, & O'Brien, 2013; Kendeou et al., 2017). In the absence of such textual information, misconceptions persist and continue to influence comprehension. For example, Kendeou and van den Broek, (2007) demonstrated that the explanation in a refutation text mitigated the interference due to misconceptions (see also Rapp & Kendeou, 2007, 2009). There was also an improvement when a refutation statement preceded the explanation. However, the refutation alone was not sufficient to significantly reduce interference from the misconception (Kendeou et al., 2014). Moreover, causality is a key feature that underpins the explanations' effectiveness; this is because causal explanations provide an inherently rich and interconnected network of knowledge (McCrudden & Kendeou, 2014; Kendeou et al., 2013).

Conclusions and Future Directions

To summarize, reading comprehension is the process of extracting and constructing meaning through engagement with written language (Snow, 2002). Reading comprehension involves the reader, the text, and the activity—all embedded into a broader sociocultural context. Thus, reading comprehension is both multidimensional and complex. This complexity has spurred the development of a wealth of models and frameworks that aim to account for different dimensions of reading. Among them are models that account for various processes that give rise to mental representations of the information in a text. Other models aim to identify the component skills and abilities that underlie reading comprehension. Because gathering information from multiple sources and documents is a necessary 21st-century literacy skill (NCTE, 2013), researchers have also developed models and frameworks that account for comprehension of multiple texts and sourcing during reading comprehension.

Comprehending written language is necessary for success through development and into adulthood. Therefore, understanding and fostering the development of comprehension skills is critical. However, despite the importance of literacy, students' comprehension outcomes worldwide have not been satisfactory (OECD, 2015). Importantly, underdeveloped literacy skills pose problems for not only individuals' quality of life, but also the global economy—illiteracy costs at least $1 trillion annually (World Literacy Foundation, 2015). Given the costs associated with poor literacy skills, future work must focus on understanding comprehension within the context of the information demands of the 21st century.

One important area of future research at the text level and activity level is identifying factors and strategies that support "deep comprehension" for different types of texts. Deep comprehension necessitates higher-order thinking skills, which require that learners analyze, evaluate, and synthesize information (Goldman, 2012; Goldman, McCarthy, & Burkett, 2015; McNamara, Jacovina, & Allen, 2015). Currently, no existing model or framework of reading comprehension can adequately account for this level of learning (Graesser, 2015), although RESOLV (Rouet et al., 2017) is a step in that direction.

One activity-level factor that may play an important role in deep comprehension is the relevance instructions provided to readers (e.g., McCrudden & Schraw, 2007), which have been shown to influence comprehension processes and learning from texts (McCrudden, Schraw, & Hartley, 2006). Future research could examine the complex interactions between reader characteristics, relevance instructions, and text properties. One potential means by which to examine these interactions is by using a "cluster approach," which involves systematically examining clusters of reader-level factors that tend to co-occur within the complex interactions between the reader and the text, followed up by more targeted experimentation (see Kendeou & O'Brien, 2018 for examples).

Another reader-level aspect of future research that has received relatively sparse attention thus far is the role of emotions in reading comprehension. Emotions are important to consider because readers will encounter information that elicits emotional responses. This is especially true given the "post-truth" era and spread of increasing amounts of controversial information on the Internet (Broughton, Sinatra, & Nussbaum, 2013; Trevors, Kendeou, & Butterfuss, 2017). With regard to emotion, there are two key dimensions to consider—valence and arousal (Russell, 2003). Valence refers to whether the subjective experience of emotions is pleasant or unpleasant. Arousal refers to the level of physiological arousal and intent to engage in activity. These two dimensions of emotions may independently influence reading comprehension via attention, working memory, motivation, learning strategies, memory processes, and self-regulation (Pekrun, 2006). Future work could examine the extent to which different emotions influence comprehension across different social-emotional contexts, such as school environments and digital learning environments.

Lastly, there is a multitude of models and frameworks that capture reading comprehension in the context of a single reader engaging with a single text. There are also recently developed models that account for a single reader engaging with multiple texts. However, there is not yet an account for multiple readers building a common situation model of the same text or multiple texts, such is the case in many classroom activities (e.g., Idol, 1987; Palincsar & Brown, 1986). Naturally, sociocultural factors would play a role when multiple readers must work together but so, too, would the many factors and interactions that influence reading comprehension at the reader level, text level, and activity level for individual readers.

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