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Word Knowledge in a Theory of Reading Comprehension

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We reintroduce a wide-angle view of reading comprehension, the Reading Systems Framework, which places word knowledge in the center of the picture, taking into account the progress made in comprehension research and theory. Within this framework, word-to-text integration processes can serve as a model for the study of local comprehension processes, that is, those that make sense out of short stretches of text. These processes require linkage between the word identification system and the comprehension system, with the lexicon in the linking role. Studies of these processes examine the influence of one sentence on the reading of a single word in a second sentence, which enables the integration of the word meaning into the reader's mental model of the text. Skilled comprehenders, more than less skilled, show immediate use of word meanings in the integration process. Other evidence is also consistent with the assumption that word meaning processes are causal components in comprehension skill.

There is no theory of reading, because reading has too many components for a single theory. There are theories of word reading, theories of learning to read, theories of dyslexia, and theories of comprehension at various grain sizes (sentence comprehension, text comprehension), appropriately targeted to a manageable part of reading. The progress of 20+ years in reading research has been guided by specific problems and flexible frameworks more than by the testing of precise theories.

We consider a set of intertwined problems of reading theory—how readers comprehend and how skill differences arise. Our analysis leads to the reintroduction of a general framework for reading that encompasses its many components, thus aiding the formulation of specific hypotheses about reading expertise and reading problems. Following the presentation of the framework we take a closer look at local text-based comprehension processes. First, we consider the broader context for comprehension theories.

THEORIES OF READING COMPREHENSION

The modern study of reading comprehension was propelled by two complementary ideas, one concerning an enriched level of comprehension beyond the literal meaning of a text—the reader's

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situation model (Van Dijk & Kintsch, 1983)—and one about the cognitive dynamics of text comprehension, the construction-integration (C-I) model (Kintsch, 1988). The C-I model made some general assumptions about the reader's cognitive architecture (e.g., limited memory) and cognitive procedures (e.g., retrieval and carry-over operations) as well as text devices (e.g., argument overlap) that support comprehension. An important value of the C-I theory was its demonstration that text comprehension could be explained by an interactive combination of top-down (knowledge-driven) and bottom-up (word-based) processes.

Earlier ideas about text comprehension had been dominated by demonstrations of knowledge-driven top-down procedures guided by scripts (Shank & Abelson, 1977) and other forms of schemata (Anderson, 1978; Bartlett, 1932). Following van Dijk and Kintsch (1983) and Kintsch (1988), text comprehension research headed in new directions, building on these models of text-knowledge interaction and creating enriched variations (Goldman & Varma, 1995) and updates on the basic idea (Kintsch & Rawson, 2005). Theories tackled one or more aspects of comprehension (for a review, see McNamara & Magliano, 2009). The landscape model (Van den Broek et al., 1996) targeted the "landscape" of activation patterns that wax and wane during reading and how the reader's goal of maintaining coherence guided these patterns. The structure building theory (Gernsbacher, 1990) also assumed a central role for coherence, which was viewed as the result of the structures built and connected by the reader, and provided hypotheses about individual differences in comprehension. The event-indexing model (Zwaan, Langston, & Graesser, 1995) elaborated the idea of the situation model toward a more comprehensive multidimensional tracking of various aspects of narrativity. Among the many issues targeted in these theories, an especially important one concerned inferences: that they were necessary for comprehension and how and when they were made (Graesser, Singer, & Trabasso, 1994). A specific contribution of this research was to show that readers make inferences that maintain coherence, including causal inferences that connect actions in narratives (Graesser & Kruez, 1993).

The current empirical status of these and other theories (e.g., embodied comprehension; Zwaan, 2003) is beyond the scope of the present article. The point they make in the present context is that broad pretheoretical contrasts—for example, verbatim versus gist memory, literal versus inferential text processing, coherent versus incoherent texts—can be addressed in models that include interactions among knowledge sources that are initiated by written word reading, rather than solely by top-down knowledge-generating inferences. Still, it is fair to say that attention to how word processes actually contribute to comprehension was minimal, with a few notable exceptions that include the role of word meaning selection in the structure building framework (Gernsbacher, 1990) and word activation processes in the construction phase of the C-I model (e.g., Kintsch & Mross, 1985).

The theories just cited are global theoretical frameworks rather than specific theoretical models. The value of a framework for something as complex as comprehension is that it provides a set of interconnected claims that, with the addition of specific assumptions, can lead to theoretical models with testable propositions and implications. Nevertheless, in contrast to well-defined models of word reading that make precise predictions (e.g., Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001), reading comprehension is too broad a target for precise models. As we illustrate in the next section, there is value in capturing this breadth in a general framework that provides a view of the component subsystems of reading comprehension.

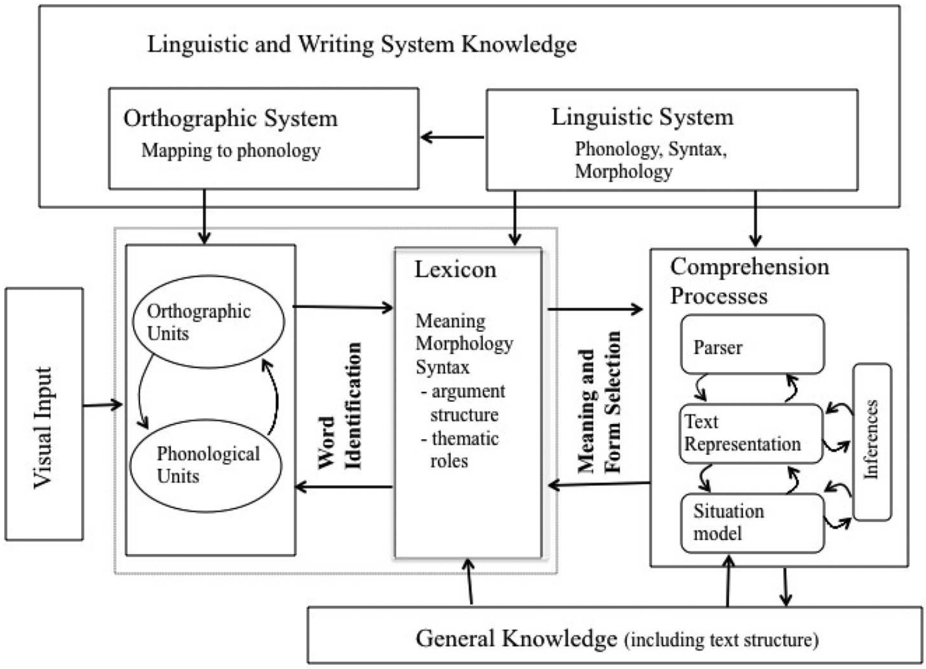

FIGURE 1 The Reading Systems Framework. *Note.* The components of reading within a language-cognitive architecture from visual processing through higher level comprehension. The key elements are knowledge sources, basic cognitive and language processes, and interactions among them. The framework allows the development of specific models (e.g., word identification models, models of inferences) and allows hypotheses about both the development of reading expertise and reading weaknesses. A particular point of focus is the lexicon, which is a central connection point between the word identification system and the comprehension system. Based on Perfetti (1999).

THE READING SYSTEMS FRAMEWORK

A general framework of *reading systems* must reflect reading more fully by adding word-level processes to the higher level processes that are the focus of comprehension research. Figure 1 presents a variation of such a framework, derived from a "blueprint" of the reader (Perfetti, 1999) and used to frame problems in comprehension (Perfetti, Landi, & Oakhill, 2005). This Reading Systems Framework makes the following claims about reading:

1. Three classes of knowledge sources are used in reading: linguistic knowledge, orthographic knowledge, and general knowledge (knowledge about the world, including knowledge of text forms, e.g., text genres).

2. The processes of reading—decoding, word identification, meaning retrieval, constituent building (sentence parsing), inferencing, and comprehension monitoring—use these knowledge sources in both constrained ways (e.g., decoding uses orthographic and phonological knowledge but not general knowledge) and in interactive ways (e.g., inferences use general knowledge and propositional meaning extracted from sentences).
3. These processes take place within a cognitive system that has pathways between perceptual and long-term memory systems and limited processing resources.

A neurobiological model of language processing by Hagoort (2005) is consistent with our systems level view. Hagoort asserted that *memory, unification*, and *control* operations are the functional core of a processing system that emerges from a distributed network of subsystems. As a reader encounters a word, input from the visual orthographic system drives operations in the temporal lobes to retrieve associated linguistic and general knowledge from long-term memory. Unification computations in the left inferior frontal gyrus integrate the word-level syntactic and semantic knowledge into the ongoing context (e.g., into a sentence). Finally, limitations in cognitive resources are managed through the application of control operations in the dorsolateral prefrontal cortex and anterior cingulate. These control structures guide operations that respond to resource limitations by, for example, retrieving context-appropriate word meanings.

The Reading Systems Framework can also guide the formation of novel theories and hypotheses of reading problems. Readers can show weaknesses in specific knowledge sources, which then affect processes that use these knowledge sources in reading. An alternative view, the dominant one, is that it is weaknesses in the processes themselves that lead to comprehension breakdown. It is typically difficult to choose between these two views. Is a measured weakness in decoding due to a processing problem involving the conversion of orthography to phonology? Or is it due to a knowledge weakness about phonology or the rules that map orthography to phonology? Is an observed problem in inference making due to a weak inference process or to a lack of knowledge that is needed to make the inference? These issues can be sorted out to a limited extent through careful experimentation. For example, in the case of the inference/knowledge issue, one can try to control for knowledge to isolate inference processes (Cain, Oakhill, Barnes, & Bryant, 2001). However, even with the best of efforts it is difficult to persuasively assess processes in isolation of other processes and, especially, in isolation of the knowledge sources on which they rely.

The Reading Systems Framework can be used to generate hypotheses about the sources of comprehension problems in several ways. One is to identify reading problems by measureable weaknesses within one or more of the components (knowledge and processes) of the framework. This works at the lower level processes, where failure in decoding defines basic reading disability or dyslexia. More specific hypotheses then focus on lower level components in the visual or phonological subsystems as sources of reading disability, with the bulk of the evidence showing a dominance of phonological processing problems (Vellutino, Fletcher, Snowling, & Scanlon, 2004).

This strategy does not work well at the higher level processes, because these depend on receiving high-quality input from word-level and sentence-level sources. Thus, careful research testing of higher level sources of comprehension problems attempts to control for some of the lower level components (e.g., Cain, Bryant, & Oakhill, 2004; Cain, Oakhill, & Bryant, 2000; Oakhill, Cain, & Bryant, 2003). The result is the identification of specific reading comprehension difficulties, of which several have been proposed, with no single difficulty emerging as definitive (Cain, 2010; Cain & Oakhill, 2006; Nation, 2005).

Another strategy is to hypothesize pressure points in the reading system. For example, the Lexical Quality Hypothesis (Perfetti, 2007; Perfetti & Hart, 2002) assumes that the lexicon is a pressure point in the system. The lexicon sits astride two reading systems: one, the word identification system, requires high-quality linguistic and orthographic information to enable rapid word identification; the second, the comprehension system, takes its input from the word identification system to build meaning units (propositions). Knowledge of written word forms and meanings, then, is central to reading and thus a pressure point for reading comprehension—a prime candidate for a cause of reading comprehension difficulty.

As a scaffold for theory development and hypotheses testing, the Reading Systems Framework allows other hypotheses about pressure points and about the interactions between reading subsystems. In what follows, however, we focus on the lexical component and its interaction with text representations.

Comprehension Skill Within the Lexical System of the Reading Systems Framework

The focus on a lexical subsystem in reading arises from the centrality of word meanings (represented in a long-term memory) as (a) the output of word identification and (b) the input to comprehension processes. This leads to research on the relations between lexical processes and comprehension processes and the following two complementary hypotheses:

1. Text comprehension depends on understanding words and integrating their meaning into a mental model of the text, and more skilled comprehenders do this better than less skilled comprehenders (Perfetti, Yang, & Schmalhofer, 2008; Yang, Perfetti, & Schmalhofer, 2005, 2007).
2. Learning words depends on acquiring information about both word forms and meanings from word-learning events, and more skilled comprehenders do this better than less skilled comprehenders (Bolger, Balass, Landen, & Perfetti, 2008; Perfetti, Wlotko, & Hart, 2005; Van Daalen-Kapteijns & Elshout-Mohr, 1981).

Both hypotheses are now empirical generalizations insofar as they are consistent with available evidence: correlational evidence for the first and correlational and intervention-based experimental evidence for the second. In the next section, we examine more closely the nature of this evidence and its implications for hypotheses about the sources of reading comprehension problems.

Comprehending texts includes comprehending words. In the Reading Systems Framework, a key set of processes links lexical outcomes with comprehension (Figure 1; "meaning and (grammatical) form selection"). Early sentence comprehension processes that build sentence constituents (e.g., noun phrases, verb phrases) and propositions (elementary meaning units) make use of this link. (Notice also the bidirectional link, which allows word learning to result from comprehension.)

These links can be studied only by online measures that expose word-level reading comprehension while it happens and not by observations made after a text has been read. There are three important methods for obtaining such measures: (a) word-by-word reading controlled by the reader, (b) eye-tracking, and (c) event-related potentials (ERPs) during text reading. The first has ease of instrumentation, but it allows reader strategies some influence. Eye-tracking and ERPs, which are measures taken without overt decisions by the reader, provide the clearest evidence of word-to-comprehension links. Each has its advantages: Eye-tracking allows natural movements of the eyes. ERPs, which generally require that the eyes not move, allow multiple word processing components (e.g., visual attention, orthographic recognition, meaning processes, syntactic processes) to be observed on a single word. Next we focus on ERP studies.

Word-to-text integration. We assume that, for a motivated reader, understanding entails a mental representation of the "situation" described by a text (Van Dijk & Kinstch, 1983). Identifying the structure and situational dimensions of this representation (e.g., Zwaan & Radvansky, 1998) and how they interact as the reader builds an understanding of the text (Rapp & Taylor, 2004) are important topics of comprehension research. For our purpose, however, we assume only that an unfolding narrative text asserts situations and events and that the reader builds and updates a situation model accordingly (Zwaan & Madden, 2004). The process of updating may have to overcome interference from older non-updated information that remains in memory (O'Brien, Rizzella, Albrecht, & Halleran, 1998), but we can ignore this complication in the case of a short stretch of text.

A key additional assumption is that comprehension proceeds along multiple input units. For example, a noun is understood through lexical meaning retrieval, a noun phrase is understood through additional referential processes, and a clause that includes the noun phrase is understood through additional lexical and parsing processes. So, for example, in reading the sentence, "The rain ruined her beautiful sweater," the following comprehension processes are centered on the understanding the word "rain": (a) retrieval of meaning of "rain," (b) establishing definite situational reference of "the rain" (cf. "a rain would ruin the picnic"), and (c) extracting a proposition in which "the rain" is the subject of "ruin her beautiful sweater" and thus the cause of the ruining event. Of course, only the first two operate on the reading of "the rain" with the predication about ruining the sweater requiring additional reading. It is these two processes that are in focus in the following analysis. Of specific interest is what happens across a sentence boundary, which is a paradigm case of text integration processes. We begin with a single sentence, from which a situation model can be constructed:

(1) *While Cathy was riding her bike in the park, dark clouds began to gather, and it started to storm.*[1]

In Figure 2, a simple scheme represents a possible situation model a reader might have from the reading of (1). The situation includes four referential entities—Cathy, the park, the bike, and dark clouds—and an event—the storm. Referents are essential in the model, because referents are eligible (unequally) for elaboration. Events are normally but not necessarily established through verbs, and these events also become eligible for elaboration. With this situation established, the text adds a new sentence:

[1]Our discussion relies on relatively simple narrative texts, which contain clear event structures to expose examples of integration processes. However, our theoretical framework and the word-to-text integration processes we examine apply to texts of all types.

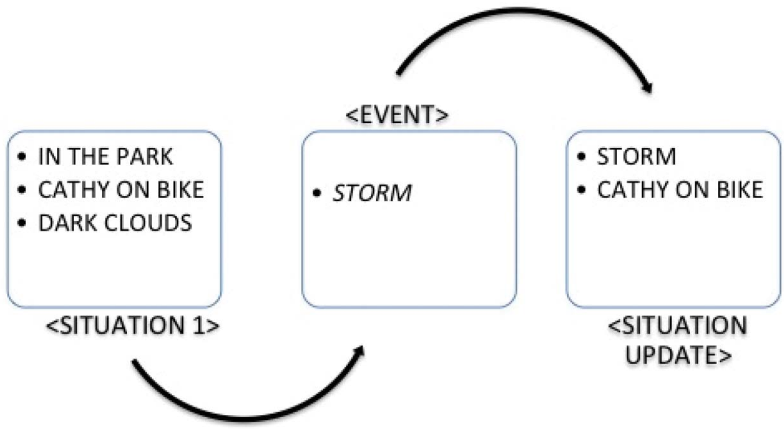

FIGURE 2 A situation model. *Note.* The model represents what a reader might understand after reading the sentence *While Cathy was riding her bike in the park, dark clouds began to gather, and it started to storm.* The general form of the model is SITUATION + EVENT (color figure available online).

(1) *While Cathy was riding her bike in the park, dark clouds began to gather, and it started to storm. The rain ruined her beautiful sweater.*

The noun phrase that begins the new sentence—*the rain*—is understood immediately in relation to the situation model. It refers to the storm event, to which it can be integrated as part of the situation model. Figure 2 would now incorporate the new event—the ruination of the sweater.

Experiments summarized in Perfetti et al. (2008), using sentences similar to (1), measured the ERP responses initiated by a target word—"rain" in the current example. When the target word appeared, the N400 component, an indicator of the degree of fit between the word and its context experienced by the reader (Kutas & Federmeier, 2000), was reduced in amplitude relative to a baseline condition (2):

(2) *When Cathy saw there were no dark clouds in the sky, she took her bike for a ride in the park. The rain that was predicted never occurred.*

Here, the N400 on the word "rain" has a more pronounced negative deflection, because initially it does not fit as easily into its context. There is no antecedent for "rain" in the preceding sentence. Equivalently, the situation model contains no referent to which the new event, "the rain," can be attached. Unlike in (1), there is no "storm" event to support the integration of "the rain" into the model. Instead the reader must build a new structure around this new event.

It is important to emphasize that the difference between texts (1) and (2) is not about their sensibility or coherence. Text (2) is fully sensible. Thus, the N400 comparison of texts (1) and (2) on "rain" is quite subtle compared with the more typical studies of the N400, which compare meaningful and anomalous sentences. For example, in a classic N400 study, an ERP recorded on "eat" in "The pizza was too hot to eat" was compared with the ERP recorded on the anomalous "drink" in "The pizza was too hot to drink" (Kutas & Hillyard, 1980). In these conditions, the N400 differences are dramatic and may be explained by expectancy violations (Kutas & Federmeier, 2000; Lau, Almeida, Hines, & Poeppel, 2009). However, in our case, a comparison is made across sensible texts that differ only in the degree to which they invite an immediate word-to-text integration process. (See Brown & Hagoort, 1993, for an N400 interpretation based on post-lexical integration processes.) Expecting a certain word across a sentence boundary seems unhelpful to comprehension; nearly any grammatical sentence beginning can continue with coherent ties to the preceding sentence. Thus the reduction of the N400 in our case is not about expectancy violations, but about integration.

The paraphrase effect and comprehension skill. The word "rain" is better integrated with text (1) than with text (2). We refer to this as the *paraphrase effect*, with the understanding that this is not exactly the everyday sense of "paraphrase," that is, expressing an idea in words different from its original expression. In our usage, paraphrase is an implicit co-referential relation between a word or phrase in one sentence and a word or phrase in a following sentence. The co-referential relation is defined by the contents of the mental representation of the enriched semantic content of the text—the situation model. The paraphrase can update the situation model modestly (or merely reinforce the salience of a referent) while maintaining coherence. Thus, in text (1), "rain" is *not* another way of saying "storm." Rather, "rain" fine-tunes the mental model by identifying a correlate or consequence of the storm, which was established in the first sentence.

The paraphrase effect reflects online comprehension, an updating of the situation model that integrates a word with a text representation. In addition to evidence for this integration process in ERP records, we discovered that skilled comprehenders showed the paraphrase effect more robustly than less skilled comprehenders, who were described as showing *sluggish* word-to-text integration (Perfetti et al., 2008). This sluggishness can have consequences for maintaining coherence across sentences, as memory resources, which are required for comprehension repairs, become less available.

Word-to-text integration can involve inferences. Indeed, one might argue that the paraphrase effect is a kind of bridging inference (Graesser, Singer, & Trabasso, 1994; Singer & Halldorson, 1996). In our previous example, a bridging inference could link "the rain" back to the storm, preserving coherence. On this description, we could say that skilled comprehenders make this bridging inference more readily than less skilled comprehenders. However, such a description seems incomplete without a focus on its lexical basis, and, further, it would beg the question of what makes this bridging inference more likely for the skilled comprehenders. Instead, we think describing the rain-to-storm link-up as a lexically based integration process (word-to-text) better captures the cognitive operations involved and frames a hypothesis for why there is a skill difference. Thus, instead of focusing on "broken" bridging processes one focuses on word knowledge and context-sensitive meaning selection processes that are required for the integration process.[2]

[2]The description as lexically based integration helps preserve bridging inferences for the more effortful and nonlexically based bridge building demonstrated by the early studies of Haviland and Clark (1974). In their example of "The beer was warm," a bridge is made from "beer" back to "the picnic supplies" of the preceding sentence. This bridge does not rest on a lexical process in which "beer" is understood to refer to "picnic supplies."

There is an important role for bridging inferences in this kind of word-to-text integration, however. If the text of the first sentence has only an implication of rain rather than establishing a rain-related event (storm), the integration process requires bridging, as in text (3):

(3) *While Cathy was riding her bike in the park, dark clouds began to gather. The rain ruined her beautiful sweater.*

When the reader encounters "rain" in (3), there is no storm event in the mental model to which "rain" can be attached. Instead, the reader makes a bridging inference, constructing a new event: Rain. This bridging inference (e.g., Graesser et al., 1994; Singer & Halldorson, 1996) is readily made, although with some cost to processing efficiency. Yang et al. (2007) observed that for texts of this type, the N400 amplitude was not significantly different from baseline. Thus, reading "The rain . . ." in sentence (3) was similar to reading "The rain . . ." in sentence (2) as far as the ERP record was concerned.

The costly bridging inference is unnecessary if, in the first sentence, the reader makes a forward or predictive inference. Such an inference would occur while reading the first sentence of (3), specifically the segment ". . . dark clouds began to gather." This inference is a prediction (it will rain) the reader might make (Graesser et al., 1994). This inference has little warrant, however, so adding rain to the mental model is a risky move. Certainly the comprehension of "dark clouds" in the first sentence allows "the rain" to be easily understood when it does appear in the next sentence. (Hence, the N400 to (3) is not more negative than in (2).) However, it does not compel a forward inference (McKoon & Ratcliff, 1992). The N400 results of Yang et al. (2007) strongly suggest that skilled readers do not make the forward inference consistently, and thus had to make a bridging inference when they came to the word "rain."

To summarize: Word-to-text integration processes are central to comprehension because they recur with each phrase. They reflect a close coupling of word identification with representations of the meaning of the text, mediated by the retrieval and selection of word meanings. Word-to-text integration processes are pervasive, and the processes that produce the paraphrase effect are only part of the integration picture. Other anaphoric processes, ranging from simple pronoun binding through more complex co-referential expressions are also relevant, as are bridging inferences. All these processes maintain coherence at variable costs to comprehension efficiency. Comprehension skill depends in part on these word-to-text integration processes. Those processes that depend on word meanings are especially likely to show individual differences, because knowledge and use of word meanings is highly variable across individuals.

Explaining further the association between reading skill and the paraphrase effect requires more research. Candidate explanations within the Reading Systems Framework include (a) individual differences in the lexicon, either vocabulary size (in a familiarity or passive knowledge sense) or more finely tuned word knowledge that supports the use of words in specific contexts; (b) cognitive architecture factors, including working memory limitations (Just & Carpenter, 1992); and (c) problems in executive functioning (e.g., Cutting, Materek, Cole, Levine, & Mahone, 2009) that can cause less effective inhibition of irrelevant word level semantic information (Gernsbacher, 1990).

More research is needed to understand the mechanisms of word-to-text integration, aside from skill differences. The cross-sentence paraphrase effect is a general language process, found in listening comprehension as well as reading (Adlof & Perfetti, 2011). Beyond this is whether the message level of comprehension (what the text means) or the lexical level (the association between prior words and the word being read), or both, are responsible for the paraphrase effect. Although the message level must be involved if the effect is about comprehension, lexical processes initiated by word identification, including associations that a word has with other words in memory and with other words in the text are part of the process. In the C-I model, associations are activated through rapid, automatic processes in the construction stage and may have no consequences for the later integrative stages of comprehension. However, if the text contains words that take advantage of the associations that are evoked unconsciously, then associations provide a head start on message-level comprehension. A final question is whether the lexical component of the text integration process takes advantage of forward association processes or uses memory-based backward processes. In our example, does "storm" in the first sentence evoke "rain" as an associate, which is then available to support integration when "rain" is encountered in the next sentence? Or is the more important process that when "rain" is read in the second sentence it resonates with the memory of "storm" from the first sentence. Both processes must occur, but we hypothesize that the memory-based process dominates across sentence boundaries.

Knowledge of Word Meanings Is Instrumental in Reading Comprehension

The paraphrase effect demonstrates a subtle role of word meanings in comprehension (in addition to their obvious role in allowing comprehension) and leads to the question of what kinds of word knowledge are responsible for integration success and comprehension more generally. The Lexical Quality Hypothesis (Perfetti, 2007; Perfetti & Hart, 2002) assumes that word knowledge (both form and meaning) is central to reading skill. High-quality form knowledge includes phonological specificity, the lack of which has been linked to problems in reading and word learning (Elbro, 1998; Elbro & Jensen, 2005). It also includes orthographic precision, which has been shown by Andrews and colleagues to have specific consequences beyond the effects of reading skill. Spelling-based lexical expertise effects are seen in lexical access (Andrews & Hersch, 2010; Andrews & Lo, 2012) and spelling/vocabulary lexical expertise effects can show subtle effects in the balance of top-down and bottom-up processes in comprehension (Hersch & Andrews, 2012).

The semantic constituent of lexical quality has a close connection to comprehension, as well established by correlations between vocabulary and reading comprehension (e.g., Adlof, Catts, & Little, 2006; Cromley & Azevedo, 2007). The impact of vocabulary on reading is usually assumed to be indirect through its role in general language comprehension. However, it is possible that vocabulary also has a direct effect on reading itself. An observation by Braze, Tabor, Shankweiler, and Mencl (2007) is interesting on this point. Across a range of adolescent and adult readers, Braze et al. (2007) found that vocabulary accounted for reading comprehension to a greater degree than it did listening comprehension. They argued that this reflects the fact that written words are more likely to fail to activate lexical representations than are spoken words. In effect, a stronger semantic connection (a more integrated set of word constituents) can compensate for lower orthographically initiated activation.

Consistent with this possibility are the results of other cross-sectional and longitudinal studies. Protopapas, Sideridis, Mouzaki, and Simos (2007) in a study of 534 children in Grades 2, 3, and 4 in Greek schools in Crete found a strong relationship among reading comprehension, vocabulary, and decoding. However, the unique contribution of decoding, relative to its shared variance with vocabulary, was negligible with vocabulary taken into account, especially beyond Grade 2. In a longitudinal study that followed 2,143 Dutch children through Grade 6, Verhoeven and Van Leeuwe (2008) found that at Grade 1 reading comprehension was accounted for by a structural model that combined word decoding and listening comprehension. Examining later grades with time-lagged correlations, they found that earlier vocabulary predicted later reading comprehension, whereas earlier listening comprehension did not.

Accounting for word meaning knowledge as part of reading provides a challenge for the assumption that decoding a word unlocks all the knowledge associated with the spoken word. The Simple View of Reading (Hoover & Gough, 1990), an expression of this assumption, would need to accommodate the direct effects of vocabulary on reading comprehension by allowing vocabulary knowledge to influence decoding (Tunmer & Chapman, 2012). Word meaning would thus contribute to reading both as a component of language comprehension and through word reading. Although the spoken language may be the main carrier of word meanings, it is the retrieval of word meanings through orthographic representations (and their integration with text meaning) that is critical in reading.

A second aspect of the word knowledge–comprehension connection concerns learning new words. (Figure 1 shows this connection by arrows from comprehension back to the lexicon.) During reading, readers implicitly infer meanings from imperfectly understood text, allowing the establishment of a new lexical entry or the refinement of an existing one. Readers of greater skill, word knowledge, and experience are more effective at this learning. Experimental evidence for this conclusion spans studies of children and adults and reveals skill differences in learning new words implicitly from text, as well as from direct instruction (e.g., Cain, Oakhill, & Lemmon, 2004; Perfetti, Wlotko, & Hart, 2005).

In the present context, the relevance of these twin aspects of the word knowledge–comprehension relationship is the centrality of word knowledge in a theory of comprehension. The word-to-text integration evidence is that skilled readers are better able to integrate words into their mental models of the text. The correlational evidence on the word knowledge–comprehension relationship and the experimental evidence on learning new words together suggest that skill differences in the integration processes may depend on knowledge of word meanings or the use of this knowledge during text reading.

In the final section, we return to the theoretical concerns we raised at the beginning, showing how the Reading Systems Framework can guide more specific hypotheses about comprehension and differences in comprehension skill.

WORD COMPREHENSION WITHIN THE READING SYSTEMS FRAMEWORK

Word reading in context is about word comprehension, which is at the center of the Reading Systems Framework. Word comprehension is the output of the word identification system and the input to the comprehension systems (sentence, text, and situation). Figure 3 is a wide-angle lens view of this part of the framework, showing (in an altered spatial orientation) the word identification system on top and the word comprehension system on the bottom. Word comprehension is word-to-text integration in this view. Word meanings stored in memory (the lexicon) are only part of word comprehension, as they (and other memory-driven associations) are activated during reading and then tuned to what the context (the representation of the situation) demands.

To return to the review of comprehension theories, we see that the word comprehension model corresponds roughly to the construction (upper part of Figure 3) and integration phases (lower part

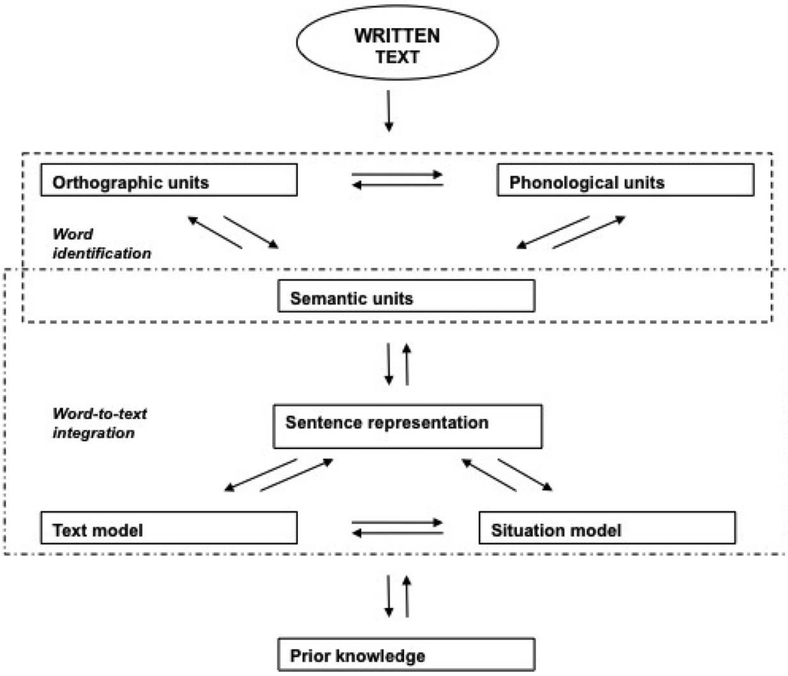

FIGURE 3 The connection between two systems that support comprehension, "The word identification system and the word comprehension system," is illustrated. As words are identified, they are comprehended in relation to the representation of the text. The comprehension process links the word to an existing referent (or event) in a mental model or extends the mental model to include a new or updated referent (or event). Semantic units activated with word identification are part of this process (the activation phase of the CI model), but the selection of meaning is influenced by the reader's immediate representation of the text.

of Figure 3) of the C-I model (Kintsch, 1988). However, we do not assume that this integration is necessarily an active process. It is at least partly (if not mainly) a memory-driven process, in which words from the recently read text and the propositions they encode (the text model) are highly accessible in memory. A word, as it is read, "resonates" with these memories, and connections are made without an active construction process, which can later tune and correct the representation. This process is adaptive for comprehension insofar as what is activated in memory is relevant and consistent with the current state of the situation model. However, even information that has been updated and is no longer relevant can continue to exert an influence on comprehension (O'Brien, Cook, & Guéraud, 2010; O'Brien et al., 1998). Active construction may become necessary when coherence breaks down and requires new structures to be built (Gernsbacher, 1990). However, the value of a more passive memory process is that text integration can occur at low cost to processing resources, and this may be the default integration processing mode within and across sentences.

It is not completely clear whether immediate updating of the situation model is sufficient to protect comprehension from the intrusion of no-longer relevant information (O'Brien et al., 2010; Zwaan & Madden, 2004). However, this issue may not matter much for word-to-text integration, as we have considered it here. This is because the relevant memory traces have been established just prior to the word to be read (although across a sentence boundary) and there is not much contradictory discarded information to produce interference. With longer stretches of text to contribute more information in memory, interference may be more likely.

There is an advantage of localizing a small part of the comprehension process for theoretical focus within the Reading Systems Framework: It allows a tractable number of comprehension processes to be considered. Here is the minimum set of the overlapping processes required for fluent word-to-text integration.

1. Rapid, automatic lexical access based on word form;
2. Rapid, automatic activation of associated knowledge from memory;
3. Access to memory for recently read text at the level of text model, situation model, or both;
4. Knowledge of context-relevant meaning associated with the lexical entry and its rapid retrieval; and
5. Word-to-text integration resulting from these overlapping processes.

For an expert reader with knowledge of word meanings and sufficient experience, these are not effortful processes. Indeed, each overlapping phase of integration can be executed with minimal resource demands, approaching automaticity. These processes can be modeled through word activation networks with feedback from semantics and memories for recently read text segments. To perform robustly over text variations, models would need to include syntactic processes, which are usually ignored in text comprehension models. The point is that the basics of a testable theory that assumes individual differences in word-to-text integration processes arise from lexical knowledge. Alternative hypotheses can be tested, for example, that such comprehension skill differences arise from memory limitations or word identification processes that are resource demanding. Furthermore, one can examine the deeper question of whether sluggish word-to-text integration (Perfetti et al., 2008) propagates upward to the higher levels, and thus helps to explain retention and higher level as well as lower level comprehension problems.

CONCLUSION

Theories (or more accurately, frameworks) of reading comprehension have moved from broad-scope ideas to more specifically targeted aspects of the overall complex problem of comprehension. This has allowed progress in the study of components of comprehension, from the role of memory, the use of inferences, and the updating of mental models. We reintroduced a broad-scope framework that makes central the role of the lexicon, a somewhat neglected component in text comprehension research. The Reading Systems Framework represents the broad set of knowledge sources, and processes that act on these knowledge sources, allowing researchers to examine specific systems and subsystems and the interactions among them.

Within this framework, we target a seemingly small yet central and recurring comprehension process, the integration of the currently read word into a mental structure that represents the current understanding of the text (the situation model). These word-to-text integration processes allow readers to continuously tune and update their current understanding. The paraphrase effect reflects a text integration process that is initiated by reading a word whose activated meanings include one that is congruent with the current model of the text, and thus can be integrated into that model. The lexical nature of this process distinguishes it from other integrating processes, such as bridging inferences, which also allow updating and keep the text coherent but at some cost to processing effort.

Individual differences in reading comprehension are seen during these word-to-text processes, specifically in the lexically driven paraphrase effect. This fact invites closer examination of whether subtle differences in knowledge of word meanings or the conditions of word use might affect word-to-text integration, as well as more global measures of comprehension. The general relationships between global comprehension skill and vocabulary and between comprehension skill and new word learning also suggest this possibility. Theoretically, our argument entails a closer view, within the Reading Systems Framework, of the interaction between the word identification system and the comprehension system that is mediated by lexical knowledge and manifest in word meaning processing.

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