An Introduction to Strategic Reading Comprehension

Arthur C. Graesser

University of Memphis

Send correspondence to:

Art Graesser
Psychology Department
202 Psychology Building
University of Memphis
Memphis, TN, 38152-3230
901-678-2742
901-678-2579 (fax)
a-graesser@memphis.edu

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Abstract

This chapter provides an overview of the conceptual, theoretical, empirical and pedagogical foundations of reading strategies. The chapter begins by offering a definition and clarification of what it means to have a reading comprehension strategy. The subsequent section contrasts three major theoretical frameworks for investigating comprehension in the fields of cognitive science and discourse processing: a construction-integration model, a constructionist theory, and an embodied cognition view. These frameworks offer different claims and commitments with respect to computational architectures and the status of strategies in comprehension. It is recommended that researchers identify the predictions of these and other theoretical frameworks when planning their empirical research on the effectiveness of reading strategies in educational settings. The chapter concludes with a discussion of some challenges that researchers will face when moving from theory to interventions and to assessments of reading comprehension strategies.

Reading is an extraordinary achievement when one considers the number of levels and components that must be mastered. Consider what it takes to read a simple story. The words contain graphemes, phonemes, and morphemes. Sentences have syntactic composition, propositions, and stylistic features. Deep comprehension of the sentences requires the construction of referents of nouns, a discourse focus, presuppositions, and plausible inferences. The reader needs to distinguish given versus new information in the text, and implicitly acknowledge what is shared among most readers in a community (called the common ground). At more global levels, the reader needs to identify the genre, rhetorical structure, plot, perspective of different characters, narrator, theme, story point, and sometimes the attitude of the author. The coding, interpretation, and construction of all of these levels are effortlessly achieved at a rate of 250 to 400 words per minute by a proficient adult reader.

Comprehension is not always effortless and fast, of course. When beginning readers struggle over individual words, reading is slowed to a near halt and deeper levels of comprehension are seriously compromised. This happens when proficient adult readers struggle with technical expository text on unfamiliar arcane topics, such as a mortgage on a house or the schematics of computer's operating system. Cognitive strategies are particularly important when there is a breakdown at any level of comprehension. A successful reader implements deliberate, conscious, effortful, time-consuming strategies to repair or circumvent a reading component that is not intact. Reading teachers and programs explicitly teach such reading strategies to handle the challenges of reading obstacles. Such strategies are the direct focus of this chapter, and indeed the entire volume.

It could be argued that reading strategies are also important for many adults who consider themselves to be skilled readers. There are basically three arguments to bolster this claim. First, many readers do not know whether they are adequately comprehending text. In research on comprehension calibration (Glenberg & Epstein, 1985; Maki, 1998), ratings are collected from readers on how well they believe they have comprehended texts and these ratings are correlated with objective tests of text comprehension. The comprehension calibration correlations are alarming low ($r = .27$) even among college students. Acquisition of better reading strategies holds some promise in helping readers improve their comprehension calibration.

Second, many readers have an illusion of comprehension when they read text because they settle for shallow levels of analysis as a criterion for adequate comprehension (Baker, 1985; Otero & Kintsch, 1992). Shallow readers believe they have adequately comprehended text if they can recognize the content words and can understand most of the sentences. However, deep comprehension requires inferences, linking ideas coherently, scrutinizing the validity of claims with a critical stance, and sometimes understanding the motives of authors. Shallow readers believe they are comprehending text when in fact they are missing the majority of contradictions and false claims. Acquisition of better reading strategies is apparently needed to crack the illusion of comprehension in readers who are settling for low standards of comprehension. They need to acquire and implement strategies to facilitate deeper levels of comprehension.

Third, nearly all adults have trouble comprehending technical expository text at deep levels even though they are skilled readers. Deep comprehension of technical text is a difficult challenge because the reader has minimal knowledge of the technical terms, key conceptualizations, mental models, and other forms of background knowledge. Even those with high relevant background knowledge and general reading skills can struggle. Researchers in my lab recently conducted an experiment on students in a college physics course who were assigned to one of three conditions: (1) work on physics problems with an intelligent tutor (called AutoTutor), (2) read a textbook on the same content for a duration yoked to the AutoTutor condition, versus (3) read nothing (Graesser, Jackson et al. 2003; Van Lehn et al., in press). Before and after training, there was a pretest and a post-test with multiple choice questions similar to the Force Concept Inventory (Hestenes, Wells, & Swackhamer, 1992), a test that taps deep physics knowledge. We were thrilled to learn that there were substantial learning gains from AutoTutor, but that is not the main news from the present standpoint. We were surprised to learn that the college students had zero learning gains from reading the textbook, and the posttest scores did not differ from reading nothing at all. A similar finding was found on the topic of computer literacy (Graesser, Lu, et al., 2004). Results such as these strongly suggest that the reading strategies of literate adults are far from optimal when considering deep comprehension. Our college students did not achieve deep comprehension on texts about physics and computer literacy even when they had a nontrivial amount of world knowledge on these topics and sufficient reading strategies to land them in college. Acquisition of better strategies of reading comprehension may best be viewed as a lifelong mission.

Some researchers (names intentionally withheld) do not routinely agree that it is worthwhile to teach reading comprehension strategies as an explicit reading objective. Some skeptics argue that the comprehension strategies will follow naturally from reading a large body of texts and from being intrinsically engaged in the content. The problem with this conclusion is that it fails to explain the above findings on comprehension calibration, illusions of comprehension, and the poverty of deep comprehension. Readers are not at all optimally comprehending texts even after decades of practice with reading.

Other skeptics raise the concern that there is a cognitive overhead in applying comprehension strategies and that this overhead can potentially interfere with learning the substantive content. There are two rebuttals to the second worry. Regarding the first rebuttal, a comprehension strategy will have a cognitive cost when first implemented, but these costs will diminish over time as the cognitive strategy becomes more practiced and eventually automatized. As in the case of all skill acquisition, the initial learning requires consciousness, is effortful, is time-consuming, and taxes cognitive resources, but after practice many skills are automatized to the point of being unconscious, effortless, fast, and unimposing in cognitive resources (Ackerman, 1988; La Berge & Samuels, 1974; Perfetti, 1985). Whether the deep comprehension strategies can be completely automatized is presently unanswered in available research, but few would doubt that practice of the strategy will reduce the overload. Regarding the second rebuttal, the reading comprehension strategies we have in mind are intimately connected with substantive content, not detached. The comprehension strategies that will be addressed in this book are sensitive, to varying degrees, to the content expressed in the text and sometimes to the type of subject matter knowledge associated with the text. No one is advocating the use of generic content-free strategies that one often finds in commercial reading programs, such as *SQ3R* (which stands for Survey, Question, Read, Recite, and Review, Robinson, 1970). The generic strategies of SQ3R are methodically applied to all texts with little or no consideration of the nature of text content. In contrast, the strategies advocated in the chapters of this volume are content-sensitive.

The remainder of this chapter is divided into three sections. The next section offers a definition and clarification of what it means to have a reading comprehension strategy. Section 2 contrasts three major theoretical frameworks for investigating comprehension: a construction-integration model (Kintsch, 1998), the constructionist theory (Graesser, Singer, & Trabasso, 1994), and an embodied cognition view (Glenberg & Robertson, 1999). These frameworks offer different claims and commitments with respect to computational architectures and strategies in comprehension. Section 3 identifies some challenges that researchers will face when moving from theory to interventions and to assessments of reading comprehension strategies.

What is a Reading Comprehension Strategy?

A reading comprehension strategy is a cognitive or behavioral action that is enacted under particular contextual conditions, with the goal of improving some aspect of comprehension. Consider a very simple-minded strategy for purposes of illustration. Teachers often instruct students to look up a word in a dictionary when they encounter a rare word that they are unfamiliar with. The context would be a word in the text that has low frequency or (more generally) is not in the reader’s mental lexicon. The strategic behavioral actions would be to hunt for a dictionary and to locate the word in the dictionary by turning pages. The strategic cognitive actions would be to read the word’s definition in the dictionary, to reread the sentence in the text with the word, and then to comprehend the sentence as a whole. One way of specifying this *dictionary-artifact* strategy is with a context-sensitive production rule that has an IF <condition states>, THEN <action sequence> format, such as the rule below.

Dictionary Artifact Strategy

IF < word W is infrequent **OR** Reader does not know meaning of word W>

THEN < (1) reader gets dictionary, (2) reader looks up word W,

(3) reader reads dictionary definition, (4) reader rereads sentence with W,

and then (5) reader attempts to comprehend sentence as a whole.>

The production rule formalism helps researchers (and potentially teachers) keep track of the details of the strategies and how the strategies get implemented. Failure to heed such detail runs the risk of misapplying the strategies, an occurrence that researchers and teachers frequently complain about. So the reader might apply the rule too often (when the condition elements are not specific enough) or too rarely (when the condition elements are too constrained). A proper tuning of the condition elements and actions is extremely important. The conditional state might be defined either objectively (i.e., the word is rare in the English language) or subjectively (the reader has never encountered the word before). Objective definitions are needed when building some computer technologies, as in the case of a computer tutor that asks the reader whether they know the meaning of low frequency words. Subjective definitions are needed when training students on self-regulating their application of meta-comprehension strategies (Azevedo & Cromley, 2004; Zimmerman & Schunk, 2001). The point of presenting this production rule is to illustrate the format and context-sensitivity of strategies, not to formulate the perfect well-crafted rule.

Most readers are too lazy to hunt for a dictionary every time they encounter a rare word. There also are frequent occasions when the nearest dictionary is miles away. So an alternative strategy is often advocated by reading instructors, namely to “infer the meaning from context.” A *contextual word definition strategy* might be:

Contextual Word Definition Strategy

IF < word W is infrequent **OR** Reader does not know meaning of word W>

THEN < (1) reader rereads previous text for definitional clauses, (2) reader reads subsequent text for definitional clauses, (3) reader rereads sentence with W, and then (4) reader attempts to comprehend sentence as a whole.>

This production rule would have obvious predictions about eye movements because the reader would have regressive eye fixations and forward directed movements in an effort to locate definitional clauses. The strategy influences the cognitive actions of eye movements, whereas there is no need for the behavioral actions of hunting for a dictionary.

There are many other potential strategies involving cognitive actions. For example, readers could be encouraged to assign the unfamiliar word to an ontological category (e.g., an animal), based on context (e.g., X ran through the meadow dodging the trees), even through the reader would not be able to reconstruct the particular subclass or exemplar of the word. Sometimes the text provides enough context to infer that the entity referenced by a word has specific attributes (e.g., it is an animal with stripes that lives in Africa), with enough specification for the reader to continue reading further and glean the major points of the text. Indeed, a good reader knows when it is not worthwhile to fuss with a precise meaning, referent, or attribute specification of a word.

Unfamiliar words can also be handled by non-strategic mechanisms. For example, many researchers have argued that readers infer the meaning of words from co-occurrences with other words in the large corpus of texts they experience (Anderson, 1990; Landauer & Dumais, 1997). The meanings of words do not normally come from explicit definitions or even from special purpose cognitive strategies during comprehension. Readers ascribe whatever attributes they can to unfamiliar words during reading without their receiving any special-purpose systematic treatment. Accordingly, a strategic treatment of unfamiliar words is a rare or intermittent event rather than the mainstream mechanism. At this point, the jury is still out on the extent to which the treatment of unfamiliar words is handled by strategic versus non-strategic cognitive processes.

Consider another strategy that has received considerable attention in recent years, namely the construction of self-explanations during reading (Chi, de Leeuw, Chiu, & LaVancher, 1994; McNamara, 2004; McNamara, O'Reilly, et al., this volume; Millis et al., 2004). When readers build self-explanations, they recruit their world knowledge and personal experiences to make sense out of the explicit text and generate plausible inferences. According to the constructivist theory of text comprehension (Graesser, Singer & Trabasso, 1994; Magliano, Trabasso & Graesser, 1999), for example, readers are encouraged to explain the meaning of the text content by generating causes of events, justifications of claims, and other content that explains *why* events in the text occur and *why* the author bothers to mention something. In a story, for example, an action performed by a character should trigger the following *character motive* strategic production rule:

Character Motive Strategy

IF < Clause N states that character C performs action A>

THEN < (1) reader retrieves from memory motives that explain A **OR** (2) reader rereads prior text for clauses with motives that explain A **OR** (3) reader constructs inferences from analogous prior experiences with motives that explain A>

Part of the explanations of characters' actions consists of the goals or motives that drive the actions. A character might attack another character for revenge, survival, rescue of a third character, entertainment, and so on. There is ample evidence that deep comprehenders construct more self-explanations (Chi et al., 1994; Trabasso & Magliano, 1996) and that comprehension improves from instructions and training on self explanations (McNamara, 2004; Pressley et al., 1992). However, researchers have not pinned down the relative timing of self explanations that come from launching the self-explanation strategy, memory retrieval from text (component 1 above), rereading prior text (2), and generating plausible inferences from prior knowledge (3) when applying the character motive strategy.

Once again, the question arises whether strategies and strategy training is really needed to generate motives that explain the actions of story characters. Perhaps a reader's rich body of experiential knowledge is sufficient to cover the motives of pretty much any action that a character performs in most short stories and novels. World knowledge may come to the rescue very quickly, without the need to deliberately and consciously hunt for motives with the same intensity that some readers do when reading a detective novel that is carefully crafted to disguise character motives. Conscious strategies of self-explanation may be superfluous or disruptive when comprehending actions in simple stories. In contrast, when world knowledge is minimal, such strategies may be particularly important and differentiate shallow versus deep comprehenders. For example, such why-questions and explanations become salient whenever instructions are read in an attempt to assemble furniture or equipment. One important research question is how background knowledge interacts with the acquisition, application, and utility of strategic comprehension strategies (McNamara, 2004; Vitale, Romance, & Dolan, 2006).

It is beyond the scope of this introductory chapter to discuss the many theoretical issues and research questions that merit investigation in order to advance a scientific understanding of comprehension strategies. However, some of these issues and questions are enumerated below:

(1) *What level of representation is being tapped by the strategy?* Strategies differ when pitched at different levels of representation: word meaning, sentence meaning, local text cohesion, mental models, global structure, versus pragmatic communication.

(2) What prerequisite knowledge or skills are needed to apply the strategy? For example, jokes are composed with pragmatic content and a rhetorical composition to convey humor, but young children often miss the point of a joke because they lack important wisdom about life or the subtle skills to process the rhetorical level.

(3) *What prerequisite knowledge or skills will yield maximal gains from the strategy?* Attempts to connect clauses in a science text in a cohesive manner can be accomplished to the extent there is background knowledge about the science subject matter.

(4) *How much training is needed for mastery of the strategy?* A 1-2 hour training session is not adequate to master most comprehension strategies. It is not sufficient to memorize verbal articulations of most strategies; it normally takes application and practice on hundreds of texts over many weeks and months.

(5) *Does the strategy need to be explicit and conscious? Or is unconscious induction adequate?* The question of whether consciousness is required is relevant to the initial acquisition of the strategy as well as the monitoring of a well practiced strategy.

(6) *Does the strategy get executed before, during, or after the mental engagement with the content and subject matter?* The relative timing of strategy execution, apprehension of text content, and recruitment of subject matter knowledge will no doubt attract the attention of researchers for the foreseeable future.

(7) *What are the relevant genres and domain knowledge for the strategy?* A genre is a category of text, such as a folk tale, a science text, or a persuasive editorial in a newspaper. A strategy that attempts to infer author intent is particularly important for a persuasive editorial and less so, if at all, for a science text. A strategy that attempts to construct a mental image would be important when comprehending a text on assembling equipment, but less so when comprehending a mortgage contract.

(8) *Is the strategy best scaffolded by a human or computer?* Some strategies are too subtle and complex to expect a computer system to scaffold. It is too tedious for humans to scaffold strategies that are simple and require thousands of practice trials.

Answers to these questions will vary from strategy to strategy. The hope is that researchers will eventually identify some meta-principles after investigating a large landscape of reading comprehension strategies.

The Status of Strategies in Different Theories of Comprehension

Discourse psychologists have developed a number of theoretical models of text comprehension during the last two decades. These models make different commitments on the role of comprehension strategies in driving comprehension. It is beyond the scope of this chapter to cover all of the models that have been proposed in recent years. Instead, we contrast three models, each of which serves as a representative of a particular class of models. A construction-integration model (Kintsch, 1998) will represent a class of bottom-up models, which would also include the memory-based resonance model developed by Myers and O'Brien (Myers, O'Brien, Albrecht, & Mason, 1994; O'Brien, Raney, Albrecht, & Rayner, 1997). A constructionist model by Graesser, Singer, and Trabasso (1994) will represent a class of strategy-driven models, which would also include the event indexing model (Zwaan & Radvansky, 1998). An indexical model by Glenberg (Glenberg & Robertson, 1999) will represent a class of embodied cognition models (Glenberg, 1997; Zwaan, Stanfield, & Yaxley, 2002). Of course, there are a variety of other models that are hybrids, such as the landscape model (Van den Broek, Virtue, Everson, Tzeng, & Sung, 2002) and the 3CAPS model (Goldman, Varma, & Cote, 1996). We select these three representative models because they offer rather different perspectives on the role of comprehension strategies in reading.

Construction-Integration Model

Kintsch's (1998) construction-integration (CI) model is currently regarded as the most comprehensive model of reading comprehension. Its remarkably simple computational architecture accounts for a large body of psychological data, including reading times, activation of concepts at different phases of comprehension, sentence recognition, text recall, and text summarization. As will soon be apparent, strategies take a backseat in the CI model. Strategies exist, but they do not drive the comprehension engine. Instead, the front seat of comprehension lies in (a) the bottom-up activation of knowledge in long-term memory from textual input (the *construction* phase) and (b) the integration of activated ideas in working memory (the *integration* phase). As each sentence or clause in a text is comprehended, there is a construction phase followed by an integration phase. A strategy is simply a piece of knowledge stored in long-term memory that is periodically activated and recruited during integration. It is mixed in the manifold of hundreds or thousands of other concepts, rules, and content during construction and integration. Simply put, strategies are nothing special other than being another set of rules that get activated and integrated.

Like most models in discourse psychology, the CI model assumes that multiple levels of representation get constructed during comprehension. Four of these levels are the surface code, the propositional textbase, the situation model, and the text genre (van Dijk & Kintsch, 1983). The *surface code* preserves the exact wording and syntax of the sentences. The *textbase* contains explicit propositions in the text in a stripped down, logical form that preserves the meaning but not the surface code. The *situation model* (sometimes called mental model) is the referential content or microworld that the text is describing. This would include the people, objects, spatial setting, actions, events, plans, thoughts and emotions of people and other referential content in a news story, as well as the world knowledge recruited to interpret this contextually specific content. The *text* *genre* is the type of discourse, such as a news story, a folk tale or an encyclopedia article. When comprehension succeeds, the representations at all of these levels are harmoniously integrated, yet there is no intentional strategy on the part of the reader to make this happen. It simply falls out naturally from the construction-integration mechanism.

Kintsch's CI model assumes that a connectionist network is iteratively created, modified, and updated during the course of comprehension. As text is read, sentence by sentence (or clause by clause), a set of word concept nodes and proposition nodes are activated (constructed). Some nodes correspond to explicit constituents in the text whereas others are activated inferentially by world knowledge, rules, and other representations stored in long-term memory. The activation of each node in the network fluctuates systematically during the course of comprehension as each sentence is read. When a sentence (or clause) S is read, the set N activated nodes include (a) the explicit and inference nodes affiliated with S and (b) the nodes that are held over in working memory from the previous sentence S-1 by virtue of meeting some threshold of activation. There are N nodes that have varying degrees of activation while comprehending sentence S. These N nodes are fully connected to each other in a weight space. The set of weights in the resulting N by N *connectivity matrix* specifies the extent to which each node activates or inhibits the activation of each of the N nodes. The values of the weights in the connectivity matrix are theoretically motivated by the multiple levels of language and discourse. For example, if two proposition nodes (A and B) are closely related semantically, they would have a high positive weight, whereas if the two propositions contradict each other, they would have a high negative weight.

The dynamic process of comprehending sentence S has a two stage process of construction and integration. During construction, the N nodes are activated to varying degrees, specified by an initial activation vector (a_1, $a_{2,}$ …a_N). The connectivity matrix then operates on this initial node activation vector in multiple activation cycles until there is a settling of the node activations to a new final stable activation profile for the N nodes. At that point, integration of the nodes has been achieved. Mathematically, this is accomplished by the initial activation vector being multiplied by the same connectivity matrix in multiple iterations until the N output vectors of two successive interactions shows extremely small differences (signifying a stable settling of the integration phase). Sentences that are more difficult to comprehend would presumably require more cycles to settle.

It is important to emphasize that the mechanisms that drive comprehension are node activations, memory retrieval, integration of nodes in working memory via the connectivity matrix, thresholds for carrying node content across sentences, and other basic mechanisms of memory and cognition. Where do comprehension strategies fit in? A strategy is simply another nodal unit that gets activated, recruited from memory, and incorporated in the connectivity matrix. The generality or specificity of the strategy depends on the history of the texts that have been read, the nature and amount of instructions on the strategy, and the amount of practice in strategy application. A strategy that is taught in a classroom on a particular afternoon would have little or no impact on the reader during subsequent weeks, months, and years. Comprehension strategies have no special status and are not built into the architecture of the CI model in any explicit explanatory fashion.

Constructionist Model

Strategies play a prominent role in the constructionist theoretical framework proposed by Graesser, Singer, and Trabasso (1994). The distinctive strategies of this model are reflected in its three principal assumptions: reader goals, coherence, and the explanation. The *reader goal* assumption states that readers attend to content in the text that addresses the goals of reading the text. When a computer manual is read, for example, it is read very differently when the reader wants to purchase the computer than when the reader wants to fix a broken hard drive. The *coherence* assumption states that readers attempt to construct meaning representations that are coherent at both local and global levels. Therefore, coherence gaps in the text will stimulate the reader to actively think, generate inferences, and reinterpret the text in an effort to fill in, repair, or take note of the coherence gap. The *explanation* assumption states that good comprehenders tend to generate explanations of *why* events and actions in the text occur, *why* states exist, and *why* the author bothers expressing particular ideas. Why-questions encourage analysis of causal mechanisms and justifications of claims. There are other assumptions of the constructionist theory that are shared by many other models, assumptions that address memory stores, levels of representation, world knowledge, activation of nodes, automaticity, and so on, but its signature assumptions address reader goals, coherence, and explanation. The constructionist theory has generated a number of predictions about reading times, inference generation, recall of text information, and summarization; as in the case of the CI model, many of the predictions have been tested and supported, although support for the constructionist model is not as extensive as for the CI model.

The notion that coherence and explanation strategies are the hallmarks of good comprehension places constraints on comprehension. These strategies determine the selection of content that gets encoded, the inferences that are generated, the time spent processing text constituents, and so on. Good readers attempt to bridge incoming sentences with previous text content and with their background knowledge. Good readers are driven by why-questions more than how, when, where, and what-if, unless there are special goals to track such information. The explanations of the motives of characters and of the causes of unexpected events in a story are much more important than the spatial position of the characters in a setting, what the character looks like, and the procedures and style of how characters' actions are performed. Such details about space, perceptual attributes, and actions are important when they serve an explanatory function or they address specific reader goals. When readers are asked to monitor why-questions during comprehension, their processing and memory for the text is very similar to normal comprehension without such an orienting questions; however, when asked to monitor how questions and what happens next questions, their processing and memory shows signs of being disrupted (Magliano et al., 1999). Explanations and why-questions are fundamental to the construction of meaning according to the constructionist model. Research on self-explanations, as in the case of SERT (McNamara, 2004) and iSTART (McNamara, O'Reilly, et al., this volume; McNamara et al., 2004), are compatible with this theoretical position, although the precise content that is affiliated with self-explanations is not necessarily restricted to answers to why-questions.

Indexical Hypothesis and Embodiment

Glenberg's *Indexical Hypothesis* (Glenberg et al., this volume; Glenberg & Robertson, 1999) will be elevated to the status of a model, for the present purposes, because preliminary sketches of a bona fide model are emerging in the research program of Glenberg and in Barsalou's (1999) perceptual symbol system. These theoretical positions adopt an embodied theory of language and discourse comprehension. The central theoretical claim is that meaning is grounded in how we use our bodies as we perceive and act in the world. Comprehension of a story is predicted to improve after children have been able to perceive and manipulate the characters and objects in a story scenario. When adults read a manual on assembling a piece of equipment, their comprehension is expected to improve to the extent that they can enact the procedures or at least form visual images of the objects and actions. Readers who have the metacognitive strategy of grounding the entities and events mentioned in the text are expected to show comprehension advantages over those who do not bother taking such extra cognitive steps.

A major point to be made, from the present standpoint, is that the predictions on the effectiveness of strategies on comprehension are dramatically different for the constructionist model and the indexical model. The indexical model would encourage comprehension strategies that involve the construction of mental images of people, objects, spatial lay outs, actions, and events expressed in the text. The constructionist model would not encourage these strategies unless they serve the master strategies of building explanations, coherent representations, and representations that address particular reader goals. Indeed, these theoretical models are hardly redundant articulations of the same phenomena with different jargon. Rather, the predictions are decisively different! Perhaps both of the models have some validity, but for different types of texts and comprehension conditions. That is a matter for future research to decide.

Challenges of Moving from Theory to Interventions and Assessments of Reading Comprehension Strategies

The contributors to this volume have proposed some reading comprehension strategies that hold some promise in improving comprehension at deeper levels. Table 1 lists the strategies and interventions that have been proposed by contributors to this volume. The particular strategies and large-scale interventions in this list cover a broad landscape of levels and components at deeper levels. There are strategies designed to improve: (a) the comprehension of sentences and local text excerpts, (b) the bridging and connecting of text constituents, (c) the grounding of the text to personal experiences and everyday activities, (d) mastery of the rhetorical structure and genre of text, (e) social interaction with experts, tutors, and peers, (f) processes of question asking, question answering, reflection, and summarization, (g) motivation, and (h) engagement. The community of researchers could hardly be accused of being narrow or paradigm bound.

INSERT TABLE 1 ABOUT HERE

This section identifies a number of challenges that our community of researchers will face when we test the impact of the reading strategies on reading improvement. Some challenges can be readily solved with available methods and technologies, but other challenges are far from being handled and will require some radically different approaches to a solution.

Clarifying the theoretical predictions

There is ample evidence that comprehension and learning from text is facilitated by a variety of comprehension strategies. Some of these strategies are used by primary school teachers who are known to be effective in teaching reading (Pressley, Rankin, & Yokoi, 1996). Other strategies not routinely used by teachers, but have been proposed by researchers as being potentially effective. Thus, there is empirical support for claims that comprehension improves by instructions on question asking (King, 1992; Rosenshine, Meister, & Chapman, 1996), reciprocal teaching (Palincsar & Brown, 1984), self-explanation (McNamara, 2004), CORI (Guthrie, Wigfield, & Perencevich, 2004), Questioning the Author (Beck, McKeown, Hamilton, & Kucan, 1997), and other strategies advocated by science communities (National Reading Panel, 2000; Snow, 2002).

Nevertheless, it is sometimes difficult to ascertain the theoretical relevance of a particular intervention. Some interventions are compatible with virtually any theory of comprehension so their value has a practical mission rather than a theoretical mission. For example, all theories would predict benefits from linking text content to personal experiences so the theoretical status of such a prediction is empty. Some interventions have a “kitchen sink” approach, with a bundle of promising strategies, so it is impossible to pin down which strategy and theoretical prediction is responsible for any significant gain in comprehension. A kitchen sink approach is pragmatically necessary when the researcher runs a serious risk from an ineffective intervention. However, links to theory still end up being murky in kitchen sink interventions. On the flip side, theories are often so subtle and complex that there is no obvious set of intervention conditions to offer practical tests of the theories. Unfortunately, there is an inherent tradeoff between pure tests of theoretical predictions and the likelihood that an intervention proves effective.

Sometimes it is unclear what a hypothesis, model, or theory predicts. When advocates of a theoretical position modify their theories or add ad hoc assumptions to accommodate empirical findings, it makes it difficult to reconstruct what really is predicted. In order to gain some clarity, it is worthwhile to assign each empirical finding or prediction to one of the following four categories: (1) directly articulated in the model, (2) naturally follows from the model, but is not directly articulated (which is a virtue of a powerful explanatory model), (3) requires ad hoc assumptions or parameters to accommodate the data or prediction, and (4) impossible to accommodate or out of scope of model. A model has greater scope when there is a dominance of categories 1, 2, and 3, and greater decisiveness when there are fewer cells with the value of 3.

In order to illustrate the proposed analytical scheme, consider the set of predictions in Table 2. The left column lists some orienting questions that would either (a) promote deeper comprehension in an intervention on readers who are otherwise shallow comprehenders, (b) elicit answer content that good comprehenders concentrate on if such content is explicitly expressed in the text, or (c) elicit inferences that deep comprehenders routinely generate. For the present purposes, a, b, and c will not be differentiated. The numbers in the cells declare the theoretical status according the four-part distinction. The models include the CI model, the constructionist model, and the indexical model that were covered in the previous section. Also included in Table 2 is theoretical framework that inspired the Questioning the Author intervention developed by Beck et al. (1997). This intervention encourages the reader to view the author as a potentially fallible individual who can be questioned about the writing content. So good comprehenders would query the author with such questions as: Why did the author make a particular statement?, What evidence is there for a claim?, and What is the relevance of an explicit statement to the message as a whole?

Table 2 illustrates how disparate the predictions are for the different theoretical models. The CI model does not offer decisive predictions about most of the question categories, but could accommodate empirical findings by virtue of ad hoc parameters. Causal explanatory content (answers to Why did event E occur?) naturally falls out of the connectivity matrix of the CI model (a virtue of a powerful model), for reasons that will not be elaborated here, whereas the content reflected in the other categories of questions would require ad hoc assumptions and parameters. The constructionist and indexical models are more decisive and explicit in their claims; there are more cells filled with 1 and 4 values. Interestingly, these two models generate rather different theoretical predictions, which would hopefully inspire empirical research to see which predictions are confirmed. Questioning the Author also offers very different predictions than the constructionist and indexing models.

Colleagues might dispute the values presented in these cells of Table 2. Indeed, there often are debates over the precise predictions of a particular model, particularly when the models change from publication to publication. The important point to be made here is that tables such as these are valuable in science and educational practice. In the arena of science, they help researchers determine whether a study will help narrow down alternative theoretical positions. In the arena of educational practice, they help researchers select interventions to test, to prepare principled protocols of interventions, and to assign theoretical credit for interventions that work. A scientific framework is increasingly useful to the extent that it motivates intervention conditions that are feasible to implement by teachers, tutors, and technologies.

INSERT TABLE 2 ABOUT HERE

Grain size of strategies

How many strategies should there be? How contextually constrained should a particular strategy be? How specific should one articulate the procedure of applying a strategy? Answers to these questions about grain size are quite different in different fields of inquiry. Researchers in cognitive and discourse psychology would like to see dozens or perhaps hundreds of strategies, each being tuned to appropriate contextual parameters. For example, strategy S might be appropriate for a particular class of readers (e.g., adults with low subject matter knowledge and general reading ability), text categories (e.g., expository texts on science), level of representation (e.g., situation model), when later given a particular type of test (e.g., multiple choice). Investigations of higher-order interactions among reader, text, task, and representation are advocated by researchers in the area of reading comprehension (McNamara & Kintsch, 1996; Snow, 2002).

Theoretical precision does not necessarily translate well into practice, however. It would be impossible to train a generation of reading teachers how to train children to use hundreds of precisely tuned strategies. They would not have adequate knowledge of cognition, discourse, and language to conduct such detailed training. It is more practical to expect a teacher to implement 5-10 strategies that are articulated at a more course grain. For example, the SERT training (McNamara, 2004) has an important strategy called self-explanation, which is a covering term for several subtypes of content elaborations that could be specified in detailed analytical theories of explanation. Self-explanation may act as an umbrella term for teachers who apply a number of different concept elaborations, many of which are not among the subtle theoretical distinctions appreciated by scientists. One might wonder what the ideal grain size is for teachers at different points in the educational process. That remains an unanswered empirical question. Perhaps teachers would welcome more subtlety, but not the detailed representations expected by a cognitive scientist.

The notion of comprehension strategies has pressed some buttons in the education community because teachers have mechanically applied the strategies. There is liability in having readers apply strategies that are not properly tuned to context. Imagine what the consequences would be if children applied compare/contrast rhetorical structures (Williams, this volume) to every text they read. That would not work well for stories and equipment assembly manuals. Similarly, it would not be adaptive to compose mental images and hierarchical structures for text content unilaterally. These considerations underscore the importance of pitching the grain size at an intermediate level that is not so crude that important distinctions are glossed over, but not so refined that the distinctions are misunderstood or ignored by teachers and researchers.

The field of psychometrics can accommodate only 3-5 theoretical constructs in its assessments of verbal comprehension (VanderVeen et al., this volume). In the verbal Scholastic Aptitude Test (SAT), there are 67 multiple choice questions and a minimum of 6 to 10 questions per construct. There is considerable discussion of what such constructs should be and how they are grounded in psychological theories (Carroll, 1987; Haladyna, 2004; Mislevy, Steinberg, & Almond, 2003). The chapter by VanderVeen et al. (this volume) reviews their efforts to incorporate cognitive theory into the College Board's verbal SAT. They attempt to identify 4 to 5 distinct-but-related constructs: (1) determining the meaning of words, (2) understanding the content, form, and function of sentences, (3) understanding the situation implied by the text, (4) understanding the content, form, and function of larger sections of text, and (5) analyzing the authors' goals and strategies. These five constructs are approximately aligned with the levels proposed by Kintsch (1998) and by Graesser, Millis, and Zwaan (1997), so some progress has been made in coordinating cognitive theory and psychometric tests.

Cognitive researchers would like to see finer distinctions than five constructs on a psychometric test. Unfortunately, there are properties of the quantitative theories that underlie psychometric tests do not permit it, even if there were hundreds or thousands of test items. The main problem is that the constructs tend to be highly intercorrelated so it is difficult or impossible to measure the unique contribution of a particular construct. We are beginning to see discourse researchers compose carefully crafted tests that make the constructs orthogonal (Hannon & Daneman, 2001), but unfortunately the tests and tasks are sufficiently unnatural that critics question their representativeness to naturalistic text comprehension. One important question for future research is to develop better tests with naturalistic texts that have cognitive theory aligned with near-orthogonal constructs in psychometric tests. Even when that happens, however, there will probably be limits to the grain size of the constructs. Will there ever be more than five?

Interventions with humans versus computers

Computers are able to train many reading comprehension strategies and are expected to take a more prominent role in the future. Computers do not have the same limitations on fatigue, memory, and grain size that human instructors face. They can potentially diagnose hundreds of reading problems, maintain a student profile on hundreds of variables, tune strategies with an unlimited degree of complexity, and flexibly tailor a particular strategy to the student's learner profile. It could be argued that human teachers are not that flexible, but that is an argument that requires empirical investigation.

Critics of computers do not hesitate to point out limitations of computers. Computers are impersonal and lack the vast history of experiences that humans possess and can use at the appropriate times and places. It is noteworthy that these two characteristics can be regarded as strengths in some contexts. For example, some students would rather work with an impersonal computer rather than be embarrassed by their deficits in front of teachers, tutors, and peers. Sometimes the human experiences that teachers share are time-consuming and irrelevant to the culture of the learner. Working with the computer is sometimes a better use of the learner's time, especially if it is tailored to the learner profile to a fine degree. These tradeoffs between humans and computers need to be grounded in empirical research to a greater extent, rather than mere opinion, ideology, and folklore.

Computers are becoming increasingly more sophisticated in providing strategy training. Conventional computer based training has for decades provided didactic information delivery on descriptions of strategies and examples of strategy use in text, video, and multimedia. However, the advanced learning environments of today are more interactive and adaptive to the abilities of the learner. These include intelligent tutoring systems and trainers that hold conversations in natural language and that have animated conversational agents (Graesser, Lu, et al., 2004; Johnson, 2001). For example, the iSTART system developed by McNamara, Levinstein, and Boonthum (2004) uses animated conversational agents to model strategies of experts, to instantiate strategies in peer agent interactions, to give feedback to learners who try to use the strategies, and to scaffold metacomprehension (analogous to the SERT training by human experts, McNamara, 2004). Modeling-scaffolding-fading techniques have been successfully integrated in many advanced learning environments. The computer systems are substantially more adaptive when they can interpret natural language of users, provide relevant feedback, and advance the interaction in ways that promote learning.

A computer system needs to analyze the activities of the reader if its goals are to be interactive and adaptive. The language contributions of the reader serve as one rich source of reader input that manifests the reader’s depth of comprehension. We are fortunate to be at a point in history when computer systems have become very sophisticated in automated analysis of language and discourse. During the last decade there have been revolutionary advances in computational linguistics (Jurafsky & Martin, 2000) and important advances in discourse processing (Graesser, Gernsbacher, & Goldman, 2003). For example, Coh-Metrix is a computer tool available on the web that analyzes texts on multiple levels of cohesion and language (Graesser, McNamara, Louwerse, & Cai, 2004, http://cohmetrix.memphis.edu,). Coh-Metrix has the potential to replace standard readability formulas, such as Flesch-Kincaid Grade Level (Klare, 1974-1975), which rely exclusively on word length and sentence length to scale texts on readability. Coh-Metrix has hundreds of measures of discourse cohesion, syntax, semantics, and word characteristics. Coh-Metrix can potentially be used to select texts for readers to read by intelligent matches to the readers' ability profiles. Coh-Metrix might also be used to analyze verbal contributions of readers when they answer questions or summarize the text.

World knowledge is needed to interpret explicit text and construct plausible inferences. The treatment of world knowledge has traditionally been difficult in computer science, but there have been some breakthroughs in corpus-based statistical algorithms. One notable example of a statistical, corpus-based approach is Latent Semantic Analysis (Kintsch, 1998; Landauer, McNamara, Simon, & Kintsch, in press). LSA uses a statistical method called "singular value decomposition" (SVD) to reduce a large Word-by-Document co-occurrence matrix to approximately 100-500 functional dimensions. Each word, sentence, or text ends up being a weighted vector on the K dimensions. The "match" (i.e., similarity in meaning, conceptual relatedness) between two bags of words (single words, sentences, or texts) is computed as a geometric cosine between the two vectors, with values ranging from -1 to 1. LSA-based technology and similar algorithms in computational linguistics are currently being used within a number of applications, such as essay graders that grade essays as reliably as experts in English composition (Burstein, 2003; Landauer, Laham, & Foltz, 2003) and automated tutors that hold conversations in natural language (such as AutoTutor, Graesser, Lu et al., 2004). In this volume, LSA is used in iSTART (McNamara et al., this volume), Summary Street (Caccamise et al., this volume), and systems developed by Magliano and Millis (Magliano et al., this volume; Millis et al., 2004).

The prospects of having computers replace human trainers becomes progressively more feasible to the extent that computers become more adaptive to the learner and capable of accurately implementing complex training strategies. Computers are more reliable, more durable, and capable of accommodating complexity. The systems also have the capacity to train teachers to use some very complex pedagogical strategies. The question of whether computers will replace humans is arguably an empirical question: Can the capacity, complexity, accuracy, cost, and power of automated trainers outstrip what can be supplied by communities of human teachers?

Closing Comment

These are exciting times for everyone who is attempting to improve reading comprehension and to understand underlying reading mechanisms. We are in the midst of revolutions in educational reform, learning sciences, cognitive sciences, neuroscience, computer science, and information technologies. The need to improve reading literacy in the United States, as well as other countries, is on the radar of the public and government agencies. The role of strategies in improving reading at deeper levels is likely to receive increased attention in the future. This is particularly true in societies that demand more expertise in science, engineering, and technology – areas where world knowledge is modest and the need for comprehension strategies is enormous.

Author Notes

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Table 1: *Strategies and strategy interventions.*

(1) SERT (Self-explanation Reading Training) and iSTART (Interactive Strategy Training for Active Reading and Thinking) (McNamara, O'Reilly, Rowe, & Levinstein)

(2) Reciprocal Teaching Method and Questioning the Author (Palincsar, Spiro, and colleagues)

(3) Concept mapping and a knowledge-focused multi-part reading comprehension strategy (Vitale & Romance)

(4) PALS: Peer-assisted Learning Strategies (Fuchs & Fuchs)

(5) CORI: Concept Oriented Reading Instruction (Guthrie, Taboda, & Schuler)

(6) Text Structure (Williams)

(7) Structure Strategy tutor (Meyer & Wijekumar)

(8) Question Asking and Answering (King, Guthrie, Johnson-Glenberg)

(9) 3D Readers (Johnson-Glenberg)

(10) Joke City (Yuill)

(11) Indexing and embodiment (Glenberg)

(12) Summary Street (Caccamise, Franzke, Eckhoff, E. Kintsch, & W. Kintsch)

Table 2: *Question that drives comprehension according to different theoretical positions*.

Question that drives comprehension	Construction-integration	Constructionist model	Indexical, embodiment	Questioning the Author
Why did event E occur?	2	1	3	3
How did event E occur?	3	3	1	3
Why did the author mention event E?	3	1	4	1
What evidence is there that event E is true?	3	4	4	1
What will occur later in the text?	3	3	3	3

(1) directly articulated in the model,

(2) naturally follows from the model, but is not directly articulated,

(3) ad hoc assumptions or parameters are needed to accommodate the data or prediction, and

(4) impossible to accommodate or out of scope of model