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CHAPTER 7

From Print to Pixels

The Evolution of Cognitive Conceptions of Reading Comprehension

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> The Internet forces us to expand our understanding of each of these elements [text, task, reader, author, context] by considering new aspects of comprehension that are clearly related to traditional comprehension areas (e.g., locating main ideas, summarizing, inferencing, and evaluating) but also requires fundamentally new thought processes.
>
> —Coiro (2003, p. 459)

From a cognitive perspective, comprehending print on a page is not isomorphic with comprehending pixels online. Online comprehension is more complicated. It places many more processing demands on a reader. To be sure, many lower-level reading processes look much the same as readers shift from print to pixels. Decoding, word recognition, and comprehension of isolated sentences look very similar whether reading on- or offline. But the similarities are fewer with higher-level processes. Interpage, intersite, and intertextual comprehension, for instance, share some, but fewer, processing properties. The nature of each medium shapes the details of comprehension processing down garden paths of different sorts. The International Reading Association's (2002) position statement on literacy and technology anticipated the shape of these diverging paths when it stated that traditional conceptions of "reading, writing, and viewing, and traditional [conceptions]

of best-practice instruction—derived from a long tradition of book and other print media—will be insufficient [in the future]" (p. 2).

Today, we see a slowly emerging consensus among researchers, educators, and the public at large that new conceptions of reading comprehension are needed (Coiro, 2005; Hartman, 2000). This consensus has been slow to emerge because so many of the differences between on- and offline reading appear to be differences of degree or frequency rather than qualitative differences. Isn't clicking on a website's hyperlinks a pretty close parallel to flipping through the pages of a print encyclopedia, quickly consulting the encyclopedia's index volume, and then jumping back to a particular section of a long encyclopedia article? Isn't the challenge of evaluating the provenance and credibility of online information a heightened version of a challenge print readers have always faced as they sift through political fliers and other literature stuffed in their mailbox? Our view is that the accumulation of many small and large differences of frequency, degree, and speed has indeed produced a qualitative change and a new kind of cognitive challenge for comprehending online. We concur with, among others, Burbules and Callister (2000), who argued that, while parallels between on- and offline reading certainly exist, hypertext makes possible "something different, and indeed virtually unprecedented" (p. 47), as well as with Coiro (2003), who asserted that online comprehension requires "fundamentally new thought processes" (p. 459). To be sure, a reader may still report that he learned more or less the same things from reading a textbook as he did from browsing a website. But researchers are now in a position to describe where and how the processes of constructing meaning in these two contexts diverge, where the processes of constructing meaning from a social studies textbook chapter on Jacksonian "manifest destiny" in fact cease to overlap with the processes orchestrated to construct meaning from information on the same topic that is dispersed over several hyperlinked and hypermedia-rich websites. These distinctive processes motivate research in online reading comprehension and shape the structure of this chapter.

EVOLVING CONCEPTIONS AND MODELS OF READING COMPREHENSION

The path toward a cognitive conception of online reading comprehension has been marked by a series of expanding "interaction frames"

(Tannen, 1979; Tannen & Wallat, 1987). These conceptual frames initially focused on the two most immediate and concrete elements of reading comprehension: the reader and the text. These initial frames were also rooted in the culture and technology of print on the page. In time, the framing of these interactions expanded, reflecting a parallel expansion in the type of questions asked, texts read, tasks prompted, methods used, theories formed, and technologies available. The path of this expansion is sketched below and organized around two major shifts in our conception of reading comprehension: (1) from offline print text toward online pixelized texts, and (2) from two interacting elements toward many complex elements interacting dynamically.

Offline Conceptions

The research on print-based comprehension has framed the elements of reading by using a range of conceptual pairings. Beginning with the most immediate and concrete level of interaction, the elements of reading comprehension were initially framed by means of a dyadic conception: reader–text interaction.

Dyadic Conceptions

The act of reading comprehension has largely been framed as a reader–text interaction. This dyadic conception of comprehension has been articulated in a number of empirical studies, research syntheses, dictionary entries, and policy reports during the last 100 years (e.g., Anderson & Pearson, 1984; Golden, 1986; Gray, 1925; Harris, 1940; Harris & Hodges, 1981; Huey 1900, 1901). As one of the first research-based policy reports to include a focus on comprehension, the 1985 National Academy of Education report *Becoming a Nation of Readers* framed comprehension as a dyadic concept, where the reader engages in "the process of constructing meaning from written texts" (Anderson, Hiebert, Scott, & Wilkinson, 1985, p. 7). The same two elements have been used to frame the interaction of comprehension in research-based methods textbooks. For example, Durkin (1993) defined comprehension as the act where "meaning is constructed through interactions between text and reader" (p. 10).

The intricacies of this dyadic interaction have been articulated by several dynamic reader–text conceptions of comprehension processes. One conception, the construction–integration model, has been devel-

oped by Kintsch and colleagues (Kintsch, 1988, 1998; Kintsch & Kintsch, 2005; Kintsch & van Dijk, 1978; van Dijk & Kintsch, 1983). This body of work envisions the text as an element composed of several overlapping levels. The micro level is composed of parsed t- or idea-units. The meso level is composed of organizational structures that provide cohesion and order for the micro-level units. And the macro level represents the conventions and regularities of genre that give overall shape to the prose. The reader element of the dyadic interaction involves the construction of a textbase (a hierarchical mental representation of information from the text) and a situation model (a representation of the text that integrates information from the reader's prior knowledge). Many elements from the textbase and situation model contribute to reading comprehension, but prior knowledge and coherence have been found to contribute the most. Thus the Kintschian construction–integration model starts from a dyadic conception of what reading involves but ultimately provides a rich picture of a complex, many-layered comprehension process.

Another dyadic conception of comprehension, dynamic text comprehension, has been developed by van den Broek and colleagues (Rapp & van den Broek, 2005; van den Broek, Rapp, & Kendeou, 2005; van den Broek, Young, Tzeng, & Linderholm, 1999). The text is envisioned as possessing properties similar to those described in the Kintschian model. What is new is the dynamic text comprehension model's focus on fluctuations in the mental activation of concepts as the reader proceeds through the text, resulting in an understanding of the text's information that emerges gradually over time. Features of the text and characteristics of the reader "jointly and interactively affect these fluctuations, influencing and being influenced by the reader's understanding and memory of what is read" (Rapp & van den Broek, 2005, p. 276).

Triadic Conceptions

Building on these dyadic conceptions of comprehension, scholars over the years have expanded the conceptual frame of reading to include a third element. This new slot—typically added in order to focus attention on a particular hitherto neglected aspect of a reader's interactions with a text—has usually been filled by one of the following: author, task, or context. With the addition of this new element to a now-enlarged interaction frame, the focus shifts from the immediate and concrete elements of reading comprehension (i.e., reader and text) to more distant

and abstract elements (i.e., author, task, or context). In each triadic conception, the reader and text are conceived in terms similar to those of the dyadic explanations outlined in the previous section. But the inclusion of a new third element both expands the frame and complicates the interactions among the elements. Three triadic conceptions of reading comprehension are found in the research literature.

A reader–text–author conception has been articulated by a number of scholars (Beck, McKeown, Worthy, Sandora, & Kucan, 1996; Harker, 1988; Nystrand & Himley, 1984; Pearson & Tierney, 1984; Shanahan, 1992). This triadic conception of reading comprehension is based on two simple questions: What would happen if the author of a text were visible to a reader? If made visible and personable, would the author view the reader as a potential ally in comprehending the text? Such questions indicate that this triadic conception is a social conception of reading comprehension, where conversations with an imagined author about his or her craft, intentions, and knowledge constitute the act of comprehension. More precisely, it is a social-perspective-taking conception of reading, where readers invoke an author and strive to think as this writer did while he or she wrote the text. Evidence indicates that by thinking beyond the words on the page and considering the author's purpose and viewpoint, along with recognizing gaps in the text, readers wrestle more vigorously with comprehending a text's meaning (Sandora, Beck, & McKeown, 1999).

A reader–text–task conception looks at the role that task plays in the interaction between reader and text (Chang, 1983; Linderholm & van den Broek, 2002; Narvaez, van den Broek, & Ruiz, 1999; van den Broek, Lorch, Linderholm, & Gustafson, 2001). Two aspects of task have been explored in the context of a triadic conception. One is how task influences readers' comprehension. Mills (1995) and Narvaez et al. (1999), for example, found that the task demands of a reader–text situation had profound effects on what was comprehended from a text. The other is how readers intentionally adjust comprehension processes to the task demands stated or implied by a range of reading activities (Linderholm & van den Broek, 2002). In both cases, the comprehension product and process of reader–text interaction is shaped by or toward stated or implied task demands.

A reader–text–context conception has been articulated in the work of several scholars (e.g., Carey & Harste, 1987; Mosenthal, 1983; Nystrand, 1987; Smagorinsky & Coppock, 1994; Smolkin & Donovan, 2001). The meaning of the context element varies widely in the research

on comprehension. It can refer to the particular setting in which a reading event occurs (e.g., a classroom), the cultural values and practices that influence a particular reader's choices and thoughts while reading, or the larger sociocultural framework within which meaning-making behavior exists. The shared feature of these varied meanings of context is the idea that sociocultural factors impinge on how the reader–text interaction proceeds. Put another way, context has been variously envisioned as a local, regional, or global variable that needs to be controlled, measured, or taken into account so that the more immediate and concrete elements of reading comprehension can be accurately understood.

Tetradic Conceptions

The broadest interaction frames for print-based conceptions of comprehension have included four interacting elements. These interaction frames still include the immediate and concrete elements of reading comprehension (i.e., reader and text), but also include two or more of the more distant and abstract elements (i.e., author, task, and context). In each tetradic conception, the reader and text are conceived in ways similar to the previously discussed dyadic interaction frames, but the inclusion of two new elements expands and complexifies the interactions among elements even more. Two tetradic conceptions of reading comprehension are found in the research literature.

A number of reports and conceptual frameworks articulate a reader–text–task–context conception (e.g., Gaskins, 2002; Organisation for Economic Co-operation and Development, 2003). The most widely circulated articulation appeared in the RAND Reading Study Group's (RRSG) report on reading for understanding (RRSG, 2002), which abstracted from the research literature a tetradic conception of reading comprehension that emphasized the dynamic interchange among the elements of reader–text–activity–context. Substituting the term *activity* for *task,* the report defined reading comprehension as "the process of simultaneously extracting and constructing meaning through interaction and involvement with written language . . . within a larger sociocultural context that shapes and is shaped by the reader and that interacts with [all the other elements] iteratively throughout the process of reading" (p. xiii).

In this conception of the comprehension act, the reader brings capacities, skills, knowledge, and experiences to the act. The text is

broadly construed as any form of "written language." (Interestingly, the 2002 RRSG report acknowledged that the idea of text comprises "any printed text or electronic text" [p. 11] and further recognized that "we live in a society that is experiencing an explosion of alternative texts" [p. xiv], yet the report ended up focusing almost exclusively on printed text.) And the activity includes the purposes, processes, and consequences associated with a particular act. The interaction of these three elements, however, occurs within the milieu of a fourth element, the larger sociocultural context that shapes and is shaped by the reader and other elements. "The identities and capacities of readers, the texts that are available and valued, and the activities in which readers are engaged with those texts are all influenced by, and in some cases determined by, the sociocultural context. The sociocultural context mediates students' experiences, just as students' experiences influence the context" (p. 12).

Another set of studies articulates a reader–text–author–context conception by drawing from work conducted at the intersection of cognitive psychology, social psychology, philosophy, and literary theory (Hartman, 1992a, 1992b, 2004). Based in research that conceives of comprehension as a fundamentally intertextual enterprise—as always shaped by and drawing on the meaning and form of other texts—this tetradic conception adds a new layer of complexity by seeing texts as irreducibly plural. According to this model, no text stands alone, sui generis. Like letters of the alphabet or paintings in a museum, texts generate meaning from within a web of similarities and differences, references and allusions. Even when the reader is consciously focusing on just one text at a time, her act of comprehension assumes and implicitly responds to a larger set of texts (Hartman & Hartman, 1993). Nor is the text the only unit of analysis that becomes plural. Because a reader often comprehends texts from a variety of stances (locating a piece of information in one text to corroborate an opinion derived from other texts, appreciating the way an author has broken with traditional genre expectations, and so forth), the notion of the singular and single-minded reader also falls apart, to be replaced by a conception of the plural, protean reader. The reader is plural in a social constructivist sense as well: meaning making is seen as an inherently social and collaborative undertaking.

As such, the text is not a single element in the interaction, but a plural one. It is one of many texts in the act of comprehending. Because texts are often comprehended in relation to other texts (e.g., an auto mechanic clarifies a set of procedures in a technical manual before

reading descriptions of parts in a distributor's catalog, after which he reads the directions on a new part requisition form), the unit of analysis is not a single print text but sets of print-based texts (i.e., "text sets") (Hartman & Hartman, 1993). Similarly, the reader is not one, but one of many in the interaction frame of comprehension. Because a reader often comprehends texts by taking on various stances (e.g., to locate a piece of information in several texts, to evaluate the veracity of information across magazine articles, to appreciate the evocative language and imagery in an author's oeuvre), or by collaborating with others (e.g., reading a news article of interest with a family member, asking a colleague to read a memo you've just received to ensure you are not misunderstanding its tone, second-grade book buddies comprehending several books together during the language arts time block), the unit of analysis for reading is not the single reader but the reader who flexibly approaches texts from various stances (e.g., Many, 1991) or who partners with other readers to comprehend a set of texts (e.g., Short, 2004).

Also from this intertextual view of comprehension, author and context are pluralized. Authors are plural in the sense that they often write with others (as co-authors, with feedback from editors, by drawing on the writing of other authors, etc.) or intend that a set of texts be read as a unit belonging to a larger text-set conversation (e.g., Sendak wrote *Where the Wild Things Are* [1963], *In the Night Kitchen* [1970], and *Outside Over There* [1981] as a trilogy that represents and re-represents a set of basic storylines, ideas, and themes that interact with other children's texts of the time [Cott, 1983]). For its part, context is pluralized because the setting-context of comprehension often changes (i.e., from home to school to work to church) and the situation-context within each setting-context is dynamic (e.g., readers comprehending a set of primary source texts in first-period history class is a situational school context potentially different than another set of peers comprehending a set of informational physics articles in fourth period or a packet of study-guide worksheets used in sixth period English as students read Shakespeare). As a whole, this tetradic conception of reading comprehension represents the reader, text, author, and context as nested and networked entities, independent of each other in an everyday sense, but interdependent in the not-so-obvious ways in which they actually function across many locations and times. Understanding where the boundary within and across elements begins and ends is a less straightforward process, but one that strives to capture the ecology in which the act of comprehension occurs.

The preceding review presents research on print-based reading comprehension as representing three overlapping conceptions of reading: dyadic, triadic, and tetradic. Each of these conceptions is composed of a frame, the elements within the frame, and the interactions among elements in the frame. Over time, the frames have broadened to include a greater number of interacting elements, although the evolution of these conceptions has not been strictly linear. As the review makes clear, research on print-based comprehension represents theoretical and material choices about the size of frame, number of elements, and type of interactions to be examined. The theoretical and material choices for online conceptions of comprehension are exponentially more complex, which we take up in the next section.

Online Conceptions

As discussed previously, the conceptual elements, interactions, and frames for online reading comprehension share "family resemblances" with offline comprehension (Prien, 2004; Wittgenstein, 1953), especially (1) when lower-level processes are compared and (2) when particular processes are considered in isolation from one another. But the resemblances between online and offline comprehension fade when higher-level processes are compared. When several elements of online comprehension are considered in relation to one another, and when reading is seen as a dynamic interaction among an increasing number of elements, a point is reached where differences of degree turn into a qualitative change.

This qualitative turn of elements, interactions, and frames for online comprehension marks a substantive change in the features commonly invoked for offline reading. Put another way, the features of offline comprehension have been refeatured as they have migrated online. Because this migration is of the first magnitude, a discussion of how the elements, interactions, and frames of online reading comprehension are being reconceived follows.

Elements

The conceptual elements of online reading comprehension share a family resemblance to those of offline comprehension in one respect: studies have used various combinations of the reader, text, author, task, and context. But as an emerging body of work, online comprehension is con-

ceived of as a hexadic ($n = 6$) set of elements: reader–text–author–task–context–technology. For example, Zhang and Duke (2008) conceived of online comprehension as: 12 readers with various tasks in mind reading across a number of online texts composed by different authors to form relevant contexts through the technologies at hand. Thus the elements of online comprehension are more numerous. As such, the conceptual adicity of online reading comprehension is greater than that of offline reading comprehension; more elements are present in the interaction frames of online reading comprehension, suggesting either the need for or reality of a more complex conception of reading comprehension (Falk, 2007; Ludlow, 1996).

The conceptual elements of online reading comprehension are multiplied in another sense, too. Online, it quickly becomes impossible to ignore that each individual element is already by itself plural. Indeed, in a typical session of online reading, as the reader clicks hyperlinks to pursue a line of inquiry from one website to another, enters terms in a search engine, types a comment in a comment box at the end of an article she just read, and adjusts her purpose for reading on the basis of other readers' comments, the very notion of a unified "individual" element quickly breaks down.

As we saw earlier, offline conceptions of reading comprehension have largely conceived of the reader, text, author, task, and context as singulare tantum (i.e., as an element singular in nature). But online comprehension has conceived of these elements as plurale tantum (i.e., as plural elements that are constituted by singular aspects) (Little, Brown, & Trumble, 2002). More to the matter, online comprehension has conceived of the elements as multiple plurals, that is, plural in several ways at once. For example, the element of text is plural online in at least two ways: plural in number and in constitution. Online text is plural in number because any "lexia text" (i.e., a segment of print and other signs on a single screen) is linked to myriad other texts that make up the meta-text being read (Landow, 1997; Rosenberg, 1999). Online text is also plural because its "textual constitution" is "made up" of textual substance drawn from other texts (Giese, 1998; Landow, 2006). To comprehend online is neither conceived of nor experienced as reading a unitary text, but instead as reading across an evolving range of texts to construct meaning that meets goals or answers questions. The online interaction frame, then, is populated by texts that are made of other texts and that in turn make up the network of other texts that readers comprehend. As Delany and Landow (1991) described, "the text [in a

Web-based hypertext] appears to break down, to fragment and atomize into constituent elements (the lexia or blocks of text), and these reading units take on a life of their own as they become more self-contained and less dependent on what comes before or after in a linear succession" (p. 10).

The reader is also plural in number and constitution. For example, online reading is conceived of as highly collaborative in practice. Students gather around a single computer in their classroom to read online texts together as they search for answers about the origins of a particular dog breed. Or students use their personal wireless laptops in a civics class to collaboratively search for texts that explain the finer points in a court battle over the teaching of intelligent design and evolution. Still yet, students in Dublin, Sydney, Wellington, Pretoria, Washington, DC, London, and Edinburgh collaboratively read a series of online texts that explain how cities and communities around the globe are designing carbon-neutral economies and lives. Traces of this collaborative reading are everywhere online. Blogs and wikis provide ample evidence that readers are jointly constructing meaning of common texts that are "intensively" read and reread (Hall, 1996). As the work of Jacobs and Gallo (2002) has illustrated, even a reader sitting at home in front of her computer screen is "reading alone together" when it comes to comprehending online.

Readers comprehending online are also plural in their constitution. They perform different "comprehending selves" when they read across online texts (Goffman, 1959; Sternberg, 2003; Tierney, 2006). These selves, which have variously been called identities, stances, and approaches, represent the plural nature that reading online affords and demands (Wiszniewski & Coyne, 2002). Flexibly and purposively marshaling the comprehension strategies that accompany the stances of these various reading selves, readers become critics of the veracity of information online, aesthetes of sudden fiction and online poetry slams, searchers for the minutiae of media star trivia, and synthesizers and linkers of disparate people, information, and events. Drawing on the metaphors of Calinescu (1996) and Goffman (1959), readers online must wear many faces and perform many selves—that is, be plural—as they comprehend their way in pursuit of texts that together make sense of a question, goal, or purpose. The online interaction frame, then, is populated by readers whose singular "I's" have become plural "we's" (Hartman, 2004)—comprehending together as they perform various reading selves.

The author is also plural. Online, authorship has been conceived of as a highly collaborative practice (Lowry, Curtis, & Lowry, 2004). A number of examples illustrate the numerically plural conception of the author in the online interaction frame. Students gather around a single computer in their classroom to compose an online text that represents their collective understanding of how a bill becomes law. A group of five students use their personal wireless laptops in a Spanish III class to collaboratively author an online text in real time using online authoring software that permits real-time coediting with peers in Madrid and Santiago (e.g., Writeboard, Google Docs); the software tracks all changes in real time, keeps all versions, stores marginal comments made by authors, and notifies authors of changes made throughout the process via RSS or e-mail alerts. Colleagues from around the globe negotiate round upon round of authoring and re-authoring a Wikipedia entry on the definition of online reading comprehension (Emigh & Herring, 2005). And writers add links to other authors' texts online, thereby implicating the many-authored nature of the texts that readers read online. In all these cases, authoring online has been conceived of as a form of "hyperauthorship," where dozens if not hundreds of authors make their mark on an ever-evolving corpus of online texts that are read by others (Cronin, 2001, p. 560). As such, authoring online has been conceived of as a distributed practice—"bowling alone together" (Cronin, 2004, p. 557)—that involves writing with "a cast of thousands" (Cronin, Shaw, & La Barre, 2003, p. 855).

Writers composing for online readers are also plural in their constitution. They borrow, adapt, appropriate, and transform texts that come to them secondhand, already imbued with the texts of other authors (Hartman, 2004). They perform different "authoring selves" when they compose from off- and online texts (Holland, Lachiotte, Skinner, & Cain, 1998; Jacucci, Jacucci, Wagner, & Psik, 2005). These authorly selves represent the plural nature that writing online affords and demands (Wallace, 2001). Flexibly and purposively marshaling the composition strategies that accompany the stances of these various writing selves, authors shape the veracity of information online by vetting it and recirculating it, borrow and recombine aesthetic features, search for and report the minutiae of media star trivia, and synthesize and link disparate people, information, and events through blogs, wikis, and MOOs. Drawing on the metaphors of Sussman (2000) and Goffman (1959), authors online must wear many faces and perform many selves—that is, be plural—as they compose texts from many other texts to make sense of a desire,

goal, or purpose. The online interaction frame, then, is populated by authors who write together as various authoring selves. As such, online authoring highlights the social derivation of writing. The name on the byline or About link indexes an authoring status that differs from the one we have associated with authorship of print on the page.

The task of comprehending online has been viewed as plural in both number and constitution. For instance, online reading has been conceived of as involving many sets of tasks and subtasks (Gebauer & Shaw, 2002). A middle school reader sitting in front of a search engine page in a browser has very little text to process initially, but after typing in a few keywords and pressing return he is reading pages of complex search results to make decisions about websites' relevance to his goals, the veracity of the information provided, and how information on a particular website compares with what he just read on other websites (Henry, 2006, 2007a). These online reading tasks are not carried out in a strictly linear fashion, but as rapid, recursive, iterative comprehension cycles where multiple self-regulated decisions and understandings drive high-level sense-making strategies (Coiro & Dobler, 2007).

The context of online reading comprehension has been conceived of as plural in two complementary ways. One is the plural-in-number concept that Cole (1996) called "context as that which surrounds" (p. 132). This conception often represents comprehension as a set of concentric circles with the reader and text interaction at the center, such as the diagram used by the RAND Reading Study Group (2002) to depict the key elements of reading comprehension research. As such, the reader–text interaction of online reading is "surrounded" by the other plural elements—texts, readers, authors, and tasks—plus a number of other contextual strands, such as socially organizing structures (e.g., classroom rules and graduation requirements) and socially interactive collaborators (e.g., peers, teachers, parents, neighbors). This host of "surrounding" elements creates contexts of various sorts. For example, the element of online texts can be thought of as surrounded by the context—which literally means "accompanying text"—of other texts to form the textual context of online reading (Hartman, 2004). There is the lexia text that the reader is currently interacting with on the screen, but this text resides in a network of accompanying texts to which it is explicitly linked and those that the reader finds and acknowledges are significant in some respect to each other (e.g., by topic, theme, genre, concept). The image of an online lexia text surrounded by the context of other texts is probably best imagined in connection with Bronfen-

brenner's (1979) instantiation of the ecology of human development as a set of embedded systems. Starting with the microsystem at the center and proceeding outward through the mesosystem and exosystem to the macrosystem, the context of any online text can be imagined as surrounded by similar tiers of texts. But a numerical sense of context need not be framed by one element in the action frame. Many other combinations of elements have been imagined for the nested-contexts approach to conceiving of online reading comprehension (Volet, 2001).

The context of online reading comprehension has also been conceived of as "that which weaves together" (Cole, 1996, p. 135). This conception, plural in constitution, represents the context of online comprehension as a threaded or woven system. Following from the Latin root of context (*contexere*), which means "to weave together" (Oxford English Dictionary, *www.oed.com/*), the context of online comprehension has been conceived as a "qualitative relation" between at least two elements (i.e., threads) (p. 135). As such, the reader, text, author, task, event, and physical environment are the context because of how they interact (i.e., weave together) as multiple elements in a single momentary process.

This conception of online comprehension requires a relational interpretation of context, one that includes the many elements of a comprehending act as part of a woven system "whenever they are relevant" (Bateson, 1972, p. 458). Imagine for a moment that an adolescent girl is sitting in front of an open Web browser at home reading pages online. She goes click, click, click with the mouse on textual links while reading. What is the relational context of her reading? It includes her, her purposes, the mouse, monitor, Web links, websites, authors of those websites, the immediate physical environment, and other elements as they work together to form the comprehending act during this moment in time. She lifts her hand from the mouse and grasps an open book lying next to the monitor; she begins reading it. By moving her hand from mouse to book the relational context has changed. The elements and relations among them have changed. Her hand now links to a new element and purpose, although many elements of her immediate physical environment remain the same. It is now the book and the purposes associated with it that become relevant for conceiving what is the new context. And if she places the book back on the table and reaches to pick up the spoon in her soup bowl on the same table to eat lunch, the relevant context changes again. In each case, the mouse, book, and spoon in her hand change the relations as to what constitutes the context. Because our minds work through elements (sometimes called artifacts or tools),

comprehension has been seen as distributed throughout the elements of reading that "are woven together and which weave together individual human action in concert" to form the relevant context (Cole, 1996, pp. 136–137). Thus the context of online comprehension is contingent upon the goals that afford and constrain the particular set of elements that interact when comprehending in a given moment. So when our adolescent reader clicks from a *Seventeen.com* column about facial skin care to an *Acne.org* text on "How to Pop a Pimple" to a blog about "Tween and Teen Acne Skin Care" to an instant messaging application to share with a friend what she is learning about the best way to care for a pimple on her face, she is changing the context for comprehending with each move of the hand, screen, text, site, and application.

And finally, the technology element for comprehending online is plural in number and constitution. Historically, technology has been a "shadow" element in the offline print environment, given that book binding, page sizing, ink choice, and so forth have always shaped and constrained a typical reader's experience and cognitive performance. But online, the prominence of digital technology as a factor increases dramatically. The reader's browser version, screen size, screen resolution, plug-ins (for rendering images, animations, etc.), Internet connection speed—all these things impinge very directly and explicitly on what the reader is able to do. Even more so, these technologies are interactive and malleable like never before. The online reader adjusts font size, screen brightness, and scroll speed to suit her needs; she also makes use of desktop and Web-based tools to support her reading experience, bookmarking websites, tagging Web content, clipping snippets of text, and so on. There are multiple platforms on which reading can occur (e.g., Windows, Vista, OSX, Linux), multiple software applications (e.g., Web browsers, PDF readers, blogs, e-mail, word processors, wikis), multiple brands of applications (e.g., Firefox, Safari, Explorer), and multiple versions of a single software application brand (e.g., Firefox 1.0, 2.0, 3.0). The effect is that the technologies that transmit pixels to display information to be comprehended online count as a crucial element of cognitive processing, more so than offline where the book's technology is less interactive and malleable. Technology, then, is as much a part of the pattern of pluralization and increasing complexity as are the other elements of online comprehension (e.g., for the reader, author, text). The online interaction frame is populated by technologies that are more prominent and protean, both in number and constitution.

Interactions

How is an online reader to manage and direct the interplay of comprehension elements outlined in the previous section? With more elements at play, the pluralization of these elements, and the resulting exponential multiplication of possible interactions among these pluralized elements, the ability to think about one's own thinking—the ability to be metacognitive—becomes paramount.

Two important dimensions of metacognition—knowledge and regulation—emerge from the culture of comprehending print offline. To know and regulate one's own thinking while reading a newspaper, for example, a reader needed three kinds of knowledge: declarative (knowledge of what), procedural (knowledge of how), and conditional (knowledge of when) (Paris, Wasik, & Turner, 1991). Equipped with facts, concepts, and vocabulary, the reader orchestrates skills like previewing, predicting, summarizing, rereading, inferencing, and questioning (to name a few) in a timely manner to make sense of a newspaper article. If the reader became aware that she was not understanding a part of the article, she could check memory to see if she had any facts, concepts, or vocabulary that would help her comprehend that portion of text better or else employ a different skill to make sense of the print on the page. Thus by drawing on her knowledge of what, how, and when, a reader could orchestrate her cognitive resources to optimize her comprehension of the printed text.

When comprehending online, are these three familiar types of knowledge sufficient for being metacognitive? The evidence to date indicates that three additional kinds of metacognitive knowledge are now elevated to positions of decisive importance—knowledge of identity, location, and goal. While not entirely new, these three forms of metacognition may be counted as "additional" in the sense that, whereas in the world of print they appeared useful in a subset of reading situations, now they appear generally indispensable.

Identity knowledge (knowing who) is now a crucial part of the metacognitive picture because the online medium affords vast numbers of authors the opportunity to invent and broadcast identities of various sorts—some blandly institutional and some ironic, some borrowed and some outright fraudulent—through online texts. In light of this new reality, readers need to know at least the basic facts about how authors construct, represent, and project online identities. For example, online readers need to know about user-authored content, and about the dif-

ferences between the text in a blog entry or blog reply and the text displayed in a multiauthored and editorially vetted wiki such as Wikipedia (Zhang, 2007). Online readers also need to know about different levels of credibility that can be assigned to an online text in accordance with its origin. For example, medical advice on a personal website created by a patient needs to be interpreted differently than information on a website sponsored by a pharmaceutical company or than information published online by an independent medical research agency such as the National Institutes of Health. To be sure, knowing who wrote something has always been important. Now, however, for better and for worse, the powers and possibilities of identity creation are hugely multiplied, and rapidly evolving technologies are bringing new forms of online identity into existence every few months. (One example: feed aggregators and online text summarization tools now make it possible to generate text whose authorship is part human, part machine.) Consequently, online readers face many more choices and challenges than before, and there is a premium on being both more creative and more critical.

Locational knowledge (knowing where) is also integral to comprehending metacognitively online. At the most basic level, knowing how to use and adapt the locational features in a Web browser's interface is a prerequisite skill for online readers. Traditional offline texts are printed on numbered paper pages of a consistent size, which serves as a constant metacognitive reminder to readers about the length of the text and their position in the text. Page numbers, together with the sensation of the physical weight of the text being read, connect the typical print reader to a very definite sense of where she is, how much reading lies ahead, and where to turn for particular kinds of guidance (e.g., where to find the table of contents or the index). Online reading is different and requires more specialized locational metacognition. To start, in an Internet browser with up-and-down and left-to-right scroll bars, the previously prevailing conception of page length and page number disappears. Faced with websites of varying length and without page breaks, online readers are challenged to locate information with the aid of new tools, such as the scroll bar or the mouse cursor. This means that, already for basic navigation purposes, online readers need to know about the conventional structure and layout of websites, such as where the tabs are, how to return to a site's homepage or find a "site map" page (if one exists), and how websites and their elements are linked and nested. This locational knowledge allows readers to see the full range of

choices they have and navigate efficiently to the most relevant information.

At the same time, these skills are about more than just finding information; they enable the online reader to orient herself and form the kinds of expectations and plans that the print reader was able to form based on her sense of being in the middle or near the end of the text she was reading. Having oriented herself in relation to a particular website's architecture, as well as in relation to "surrounding" websites, the online reader is in a position to set goals, to choose to read long pages in their entirety or to jump from one page to another for the sake of comparison or contrast, to drill down to less-trafficked pages or focus on top-level pages, and so on. At a more advanced level, locational metacognition is crucial as online readers move beyond orienting themselves along already well-trodden Web pathways (such as the interlinked pages of an existing website) and engage in trailblazing more idiosyncratic pathways of their own. This blazing of new pathways is in fact what happens every time an online reader uses a search engine. As the online reader scans the search results, and then fine-tunes her search terms and clicks "search" again, she creates a new map to a new information landscape. Thus the online reader's locational knowledge is, and has to be, both retrospective (focused on already existing or already visited locations) and prospective (focused on locations and itineraries yet to be created). This locational knowledge is what saves online readers from the type of textual vertigo that can easily strike as one wades waist deep—figuratively speaking—through the torrent of textual resources available through the Web. Thus locational knowledge is essential not only for knowing where particular features and information are located, it is essential for orienting oneself in a website, or more generally, in cyberspace (Lawless & Schrader, 2008; Leander & McKim, 2003).

Goal knowledge (knowing why) provides sustained purposes for comprehending online. One of the primary metacognitive challenges in online reading is that of openness. As Burbules and Callister (2000) explained, "this [online] environment provides much greater freedom in making determinations as a reader of a text about what relates to what, or what ideas should follow or precede others" (p. 45). This "freedom" is at the same time a metacognitive challenge. It represents a significant change from the cognitive activity profile of a typical print reader. Without explicit reading goals and focus, online readers may easily become lost and overwhelmed in the boundless online environment. As Delany and Landow (1991) explained, "Hypertext has no center . . . [which]

means that anyone who uses hypertext makes his or her own interests the de facto organizing principle (or center) for the investigation at the moment. One experiences hypertext as an infinitely decenterable and recenterable system" (p. 18). Seductive details, images, ads, titles, videos, and the sort can reshape the focus or redirect the goal at any click along the way. As Coiro (2003) noted, "Hypertext and interactive features can offer too many choices and too many animations that may distract and disorient otherwise strong readers" (p. 462). Consequently, the ability to set and manage clear reading goals becomes absolutely essential. This metacognitive ability enables an online reader to formulate relevant and realistic goals, categorize and evaluate Web content in relation to these goals, adjust goals in response to what the reader finds is available and relevant, monitor progress, and determine when the goal has been attained (Zhang & Duke, 2008). Goal knowledge helps the online reader stay focused and not waste his time on eye-catching but ultimately irrelevant information. It allows an online reader to make efficient and situation-appropriate decisions regarding information or knowledge "saturation": whether he has satisfied his initial goals for reading, whether he needs to form a new reading goal, and what connections exist between original reading goals and emerging ones.

These three additional types of metacognitive knowledge (identity knowledge, locational knowledge, and goal knowledge) do not supplant earlier forms of declarative, procedural, and conditional knowledge. Rather, they extend and enrich them in startling ways. They are complementary forms of knowledge that provide a fuller set of metacognitive resources that readers can draw upon to comprehend in a more complex and open textual environment. What is it about comprehending online that creates these additional forms of knowledge? Simply put, the metacognitive challenge/burden is increased when comprehending online. Reading online places significantly greater metacognitive demands than offline print reading on readers' knowledge and control (Coiro & Dobler, 2007; DeStefano & Le Fevre, 2007). This is so not just because readers are learning about the affordances of new technologies and tools (which keep evolving) and daily encountering new kinds of texts, but because online there are so many more choices, more pathways, and more juxtapositions, that for most readers there's a dramatically bigger need for metacognitive oversight and strategizing. The nature of the relationship between heightened metacognitive activity and comprehension may be highly variable (Kiili, Laurinen, & Marttunen, 2008, 2009; Zhang & Duke, 2008).

Frames

How are these newly constituted elements and newly enriched metacognitive interactions framed when a reader comprehends pixel texts online? The answer lies in an emerging contrast between the conceptual frames for off- and online reading. The frame for comprehending print on the page has largely been a static frame, with dyadic, triadic, or tetradic interactions among elements at play. As conceived, multiple vectors of influence occur between different elements (reader, text, task, author, context) within the offline reading frame, but the elements, interactions, and frame exist—or at least give the appearance of existing—in a relatively stable, enduring system.

In contrast, the frame for comprehending pixels on the screen has emerged as a dynamic frame, with *n*-adic interactions among exponentially multiplied elements and interactions. As conceived, a dynamic frame highlights the fact that these vastly multiplied elements directly influence each other, with the result that reader, text, task, author, context, and technology actually and visibly co-evolve, not just gradually, but in the course of a typical act of comprehending online. Put another way, when reading online a reader is faced with much more than simply a multitude of elements. In very explicit ways (unlike in the offline print environment, where these things are implicit and not directly experienced by most readers), a reader online interacts with elements that actually mutate as she reads. Thus, for example, a reader's initial purpose/question and the first search she runs in a search engine together define the contours of a provisional, projected/anticipated text. But this "definition" of the text being read is almost immediately adjusted. As she clicks to a page and scans the headings, clicks on an audio clip or backtracks to her search results to select a different website, the contours and substance of the text change. In the print world, the reader would typically consult a stable index and then flip backward and forward to scan pages within the confines of a single book; online, the reader is, in effect, creating an index, and then culling and discarding pages from a vast archive of texts to construct a "text of the moment" or a "text fitted for her present purpose." The nature of the online reader's reading activity mutates as well. For example, coming to a website where links to further information take the form of animated, mouse-activated buttons on an image, the reader must switch reading modes and become, for a minute, a reader of images and diagrams.

In summary, the new frame for online reading is impossible to represent in a two-dimensional diagram with labeled elements arranged on the page in a more or less intricate pattern, with a certain number of arrows indicating interactions. The new frame for online reading must be conceived in three-dimensional or *n*-dimensional terms and, metaphorically, as the traversal of a system. This system is dynamic and evolving and simply cannot be mapped in advance, since the elements and interactions made while comprehending from point A to point B actually change the potential frames, elements, and interactions between and among points B, C, D, and so on.

IMPLICATIONS

In this chapter we have described the evolution of cognitive conceptions of reading comprehension from offline to online by tracing three trajectories. One trajectory is the expansion of elements at play in the act of comprehension, in terms of both number and constitution. A second is the shift from simple interactions among the elements of comprehension to more complex interactions. And a final trajectory is the shift from a relatively fixed frame of interaction for comprehension's elements to more dynamic frames for these interactions. The implications of these trajectories for how we practice, assess, study, and conceive of comprehension follow.

First, the evolution from print on the page to pixels on the screen suggests that a "simple view of reading" (Hoover & Gough, 1990, p. 127) is no longer tenable for skilled online comprehension. While evidence at one point in time could have permitted the assertion that reading is reducible to two interacting elements (such as readers' decoding skills and language comprehension, in the simple view of reading), the evidence and argument put forth in this chapter suggest otherwise. Today, understanding the elements, interactions, and frames that are at play when a reader comprehends online is at least as complex conceptually as so-called rocket science (cf. Moats, 1999). We say "at least" because the idea of rocket science may not sufficiently capture the truly Gordian character of the model we have sketched, whose intricacies resemble the interdisciplinary strands of nanotechnology, quantum mechanics, social network analysis, computational neuroscience, design semiotics, and cognitive flexibility theory. Indeed, the evidence from such synthe-

ses as Coiro, Knobel, Lankshear, and Leu (2008) and the New Literacies Research Team (2007) suggests that to develop a more fully conceptualized contemporary cognitive view of online reading comprehension will require more than a description of the "most intricate workings of the human mind" (Huey, 1908, p. 6), since the mind of a reader is only one of the interacting elements in the deictic frame (Leu, 2000) of online comprehension that includes other readers, as well as texts, tasks, authors, contexts, and technologies. Thus the pattern of research data from the first decade of the 21st century suggests a cognitive conception of online comprehension that is more complex, iterative, and protean than Huey (1908) could have ever imagined a century earlier.

Second, the evolution from print to pixels suggests that the spectrum of texts, tasks, contexts, and technologies populating curricula needs to be more inclusive. With everyone—from children to retirees—doing more and more of their daily reading online, restricting the range of text genres and formats taught in our schools risks leaving rising generations of readers ill prepared for the reading challenges and opportunities they will face in their personal and professional lives (Duke, Schmar-Dobler, & Zhang, 2006). From the earliest grades, students need to start building the knowledge and strategies they will need to access and interpret digital information. Indeed, as Malloy and Gambrell (2006) pointed out, the future is already here:

> Many elementary students are already adept at searching and surfing, using reading and spelling in ways not explicitly taught. Reading online is not only something that many students do in their leisure time but is also a skill they will need to develop as they learn to research and create in their middle school years and beyond. (p. 482)

At the same time, new texts and technologies require new lesson plans; most students will benefit very little from simply being turned loose on the Web without guidance or training (even if school "net safety" policies were to permit this). Today, then, sustained attention is urgently needed on how K–12 education can best equip all students with the strategies and skills they need to be resourceful and effective comprehenders of online information, as well as discerning and critical evaluators of online sources. Furthermore, not making online navigation and reading comprehension a priority for *all* students—regardless of how they score on traditional measures of reading proficiency with print texts—will only exacerbate existing achievement gaps and create new

ones (Henry, 2007b; Leu et al., 2009). Fortunately, much good work is already happening in these areas (e.g., Afflerbach & Cho, 2009; Castek, 2008; Coiro, 2007, 2009a; Coiro & Dobler, 2007; Eagleton & Dobler, 2007; Eagleton, Guinee, & Langlais, 2003; Henry, 2007a, 2007b; Salmon, 2003), and we hope to see this work spread and accelerate in the years ahead.

A third, and related, suggestion is that comprehension pedagogy needs to redouble its efforts to equip readers to learn for themselves and to make self-regulation and improvement of reading comprehension strategies an expected and familiar aspect of reading for all readers. This suggestion emerges from our earlier discussion of the increased prominence of metacognitive knowledge and strategies in online reading. Given that online readers are required to orchestrate more different processes and strategies than print readers and face many more choices (regarding which Web tools to use, which hyperlinks to follow, how to delimit the contours of the text at hand, etc.), it seems appropriate for teachers at all levels of education to devote more time than before to instruction and practice in metacognitive knowledge and strategies. The results from studies with print-based reading and instruction strongly suggest the effectiveness of teaching reading comprehension strategies (Pressley & Harris, 2006). Similar studies with online texts are still few and far between (cf. Leu et al., 2005; Castek, 2008; Coiro, 2009a; Stadtler & Bromme, 2007; Zhang, 2007). However, it seems reasonable to expect that instruction in metacognitive strategies tailored to online reading will be similarly beneficial to younger and older readers. As new technologies for presenting and processing text continue to be developed at a breathtaking pace (consider free Web tools such as *www.wordle.net*, *www.diigo, com*, *delicious.com*, *www.ibreadcrumbs.com*, and *ultimate-research-assistant.com*, and extrapolate from there), students also need to be adept at applying their metacognitive knowledge and strategies to making choices about how to encounter and interact with text for different purposes, using the interfaces and the tools that are most beneficial for them. Looking ahead, we anticipate that the practice of comprehension will become ever more deictic, shifting in form, function, and purpose as the underlying technologies for representing textual information continue to evolve in ways we cannot anticipate.

A fourth suggestion, building on the previous two, is that we need new instruments to assess online reading comprehension. These instruments may incorporate traditional reading comprehension questions from existing instruments but will also assess the skills and strategies

that, for online readers, are now essential ingredients of successful reading activity: efficient searching for information, evaluation of sources, synthesizing information from two or more sources, accessing information in different media, and so forth. The need for these instruments is urgent for at least three reasons: to provide reliable data about what online readers can and can't do; to show which curricula, teaching methods, and technologies are associated with the best learning outcomes; and to prod the research and assessment communities to keep sharpening their focus on the key underlying constructs of online reading comprehension. In 2009 the fourth international PISA assessment was administered in 22 of the 67 main survey countries, and for the first time included a 30-minute section assessing the reading literacy of 15-year-olds with electronic texts (Searle, Lumley, & Mendelovits, 2009). In the near future, we can expect to see other assessments and standardized tests begin to move in the same direction (Coiro, 2009b; Leu et al., 2008, 2009; Searle et al., 2009). All these assessments face the challenge of not overemphasizing narrowly defined skills (such as using Boolean search operators) or particular tools and technologies (such as e-mail programs) but instead probing key underlying cognitive abilities (formulating questions, breaking a problem into component parts, synthesizing and communicating results, etc.).

Fifth, the evolution of conceptions of reading comprehension suggests two related conclusions: that research on online comprehension is in its infancy, and that the maturing of scholarship on the cognitive aspects of online comprehension will require the highest forms of imaginative rigor that reading research has yet seen in the scholarly literature. Thanks to research by Leu (2000), Coiro and Dobler (2007), Zhang and Duke (2008), Coiro et al. (2008), Muller-Kalthoff & Moller (2006), and others, we have taken important first steps toward describing and understanding the skills and strategies required for successful online reading. But there is much we don't know, and much that is extremely difficult to study using traditional study designs and methods. As we have seen, one obvious example of this difficulty pertains to the way online readers choose what to read and how much to read; given that no two online readers follow exactly the same reading itinerary, and given the virtual disappearance of the idea of a stable, unitary text, researchers face formidable challenges in terms of (1) disentangling and then controlling a large number of variables and (2) establishing a basis for generalizations. These difficulties are further complicated by the fact that the technologies of online reading continue to evolve at a rapid pace. Can results

obtained from subjects using version 1.8 of a particular Web browser be compared with results from an earlier study where subjects used version 1.2? Possibly, but not without a burdensome set of caveats, limitations, stipulations, and provisos. At the same time, today new possibilities exist for observing and tracking reader behavior. For example in digital environments, tools abound for tracking the search keywords readers use, the websites they visit, the time they spend on each page, the hyperlinks they click, and so forth. As researchers get better at harnessing these data-harvesting features, we can expect to learn a great deal about the behaviors of large numbers of readers. The reading comprehension research of the future will need to triangulate these kinds of data with nano-grained observations of individual online readers.

Finally, the evolution suggests that we will need to conceive, execute, and disseminate research about online comprehension at breakneck speed. Although the underlying cognitive processes evolve more slowly, new technologies and new tools for reading are evolving so rapidly that findings based on a particular tool or a particular aspect of online reading (such as sorting and evaluating search engine results) may have a very short shelf life. By the same token, the "goodness of fit" for any working model of online reading comprehension will become increasingly time sensitive; data collected to understand the forms of comprehension made possible by new tools, texts, and tasks will likely not fit the model constructed from data just a few years ago (e.g., Small, Moody, Sidarth, & Bookheimer, 2009). At the same time, while nothing we say about reading can today be carved in stone (if it ever could be), it seems particularly important at present to articulate a working model of what online reading comprehension looks like. The practical relevance and usefulness of such a model has never been greater. Clearly, the transition from print to online reading is fraught with tensions and frustrations, as well as tremendous opportunities for an enhanced cognitive conception of reading comprehension. An evolving and cohering cognitive model of comprehension will help everyone—classroom teachers and researchers, policy makers and nonspecialist commentators—steer clear of hyperbolic claims for and against online reading (as though online reading were an "issue" one could be for or against [see, for e.g., Bauerlein, 2008]) and instead focus on addressing problems and frustrations and taking full advantage of benefits and opportunities (Leu, O'Byrne, Zawilinski, McVerry, & Everett-Cacopardo, 2009). Our aim in this chapter has been to survey past developments and provide context for the articulation of such a working model.

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