Comprehension processes in digital reading

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Abstract

The internet offers readers the unique opportunity to access rich information scenarios, but doing so requires the use of advanced digital reading skills. Examples of such scenarios are searching and acquiring information from multiple sources (e.g., hypertext, images, videos) and participating in the social exchange of information (e.g., web forums, social networks, commenting newspapers). In such scenarios, the reader has to cope with a) the constantly growing number of available information sources, b) the different formats in which digital information is presented, c) the varying quality of the information available. To deal with these affordances, individuals need to possess advanced reading skills that go beyond what is needed to understand a single text. Such skills include: a) search and navigation skills to select relevant web pages and hyperlinks and to avoid getting lost in hyperspace; b) integration of multiple pieces of information and multiple presentation formats (texts from different web pages, text and animations); and c) critical evaluation of information (e.g., assessing the trustworthiness of the information on a web page and evaluating the quality of a comment from a social network). Existing literature suggests that children and adolescents possess some of these skills, but that students at all levels struggle in complex scenarios. In the present chapter, we aim to review the literature regarding the skills needed to master the affordances of advanced digital reading scenarios.

Introduction

One of the goals that readers pursue in digital environments is to acquire knowledge from a variety of hyperlinked sources. These need to be navigated, they involve a variety of formats, and they often vary in terms of quality (from comprehensive reviews from experts, to less coherent blog posts by laypersons). Competent digital reading

involves mastering the skills needed to cope with those characteristics: *navigation* of hypertext documents (e.g. selection of what sources to read, how to sequence the reading), understanding and *integrating* different sources of information (e.g. connecting information from different web pages) and *evaluation* of information (e.g. evaluating the quality of the claims in a web page) (Afflerbach & Cho, 2010; Leu et al., 2015).

Established models on text comprehension are relevant to digital reading, but they do not necessarily account for the wide range of contexts that readers may encounter when entering complex text environments (McNamara & Magliano, 2009; Rouet, 2006). The three competencies we emphasize here are, however, clearly related to basic processes described in contemporary models of text comprehension. Integration is highlighted as a central process in those models (see McNamara & Magliano, 2009) and evaluation has also been underscored as a central process in readers' efforts to extract meaning from text (Singer, 2013). Navigation has traditionally been studied as a process distinct from comprehension of a single text, however, because it is considered to play a particularly important role in hyperlinked digital environments (e.g. Cho, 2014; Leu et al, 2015).

The three competencies may be closely related and readers' engagement in any one of them may support or trigger the two others (Figure 1). For example, a student may work on an inquiry assignment on dinosaur extinction and start by googling the term (=navigate). A Search-Engine Results Page (SERP) shows a number of potential information sources with the first two representing competing theories about the issue. Thus, the student needs to study both in order to identify the nature of the controversy (integrate) and consider whether they complement or contradict each other. Also, the student needs to evaluate if both sources seem reliable. If not, more navigation may be

needed in order to find relevant and useable information sources. Hence, there is a reciprocal relation between the three competencies.

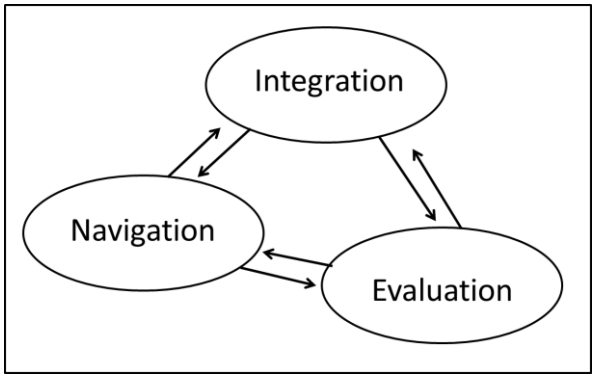

Figure 1. Three main competencies of comprehension processes in digital reading

In the following, we summarize the available knowledge on the three main competencies. For each competence, we *review* current findings on the spontaneous application of the respective competence, identify *individual differences* in the mastery of the competence, and discuss how the *design of digital reading interfaces* may influence its application. In a separate section, we outline the *main methodologies* used to study comprehension processes in digital reading. For expository purposes, we treat each of the three competencies as separate entities although, as mentioned, they are interdependencies. It also is important to note that the degree to which each competency is needed varies from task to task (e.g. searching for medical information, integrating documents for class assignment).

At the end of the chapter, we discuss major aspects of digital reading that remain unresolved and suggest future directions for research, including some aspects related to the interdependencies of the competencies identified.

1. Navigation

When reading to learn, efficient navigation is essential to handle the vast amount of information available on the internet, to ensure that readers construct a coherent

representation of the issue while avoiding distraction and becoming lost in cyberspace. This competence involves not only searching and scanning for goal-relevant information, but also sequencing navigation towards relevant information through hyperlink selections (Cho, 2014).

1.1. Navigation: description of the competence

When searching and scanning for relevant information readers must specify an initial problem space to be fulfilled, such as finding a particular datum, answering a comprehension question, or building a deep understanding of an issue. Such problem space defines what type of information readers already have and what is still needed and is thus relevant for their task (Brand-Gruwel, Wopereis, & Walraven, 2009). Readers may then access a search engine and create a specific search query that represents their information needs, or directly jump to a known web page with potentially relevant information. The identification and selection of potentially relevant hyperlinks from a SERP requires that readers evaluate the relevance of the information.

1.1.1. How readers select web pages

Search engines help their users sort through the huge amounts of information that are available on the internet and to find documents relevant to their current information needs. However, readers still require choosing between a large number of alternatives for which only sparse (mostly text-based) information, namely a title, an excerpt from the respective web page, and its URL (uniform resource locator), are provided (Rieh, 2002; Wirth, Böcking, Karnowski, & von Pape, 2007). Based on this information, predictive judgments about the relevance and trustworthiness of available documents have to be made (Rieh, 2002). There is large empirical evidence that in such decision situations of high uncertainty individuals often rely on heuristic cues to decide which

alternatives to select instead of a systematic evaluation of all given information (e.g., Hilligoss & Rieh, 2008; Metzger, Flanagin, & Medders, 2010; Wirth et al., 2007). Such cues, for instance, can be (a) the ranking position of the search result in the SERP, as readers spend most attention to the search results at the top of the first SERP and to predominantly select these links (Fu & Pirolli, 2007; Wirth et al., 2007), (b) keywords indicating a high semantic relevance of the website to a user's current information need (Fu & Pirolli, 2007; Pirolli, 2007; Rouet, Ros, Goumi, Macedo-Rouet, & Dinet, 2011), and (c) source cues such as information about the type of the website (e.g., an official institution, a forum, or a shop) indicating the trustworthiness of an information source (Hilligoss & Rieh, 2008; Kammerer & Gerjets, 2014a; Rieh, 2002).

In summary, readers tend to use heuristics to quickly select relevant web pages for their goal and, during this step, seldomly evaluate the quality of the results to filter less reliable pages. Interestingly, failing to use source cues at this step is related to lower learning outcomes in class assignments (Goldman, Braasch, Wiley, Graesser, & Brodowinska, 2012; Wiley et al., 2009), which suggests that navigation and evaluation competencies should work in conjunction to ensure that readers select both relevant and reliable pages.

1.1.2. How readers navigate across web pages

Once readers select a web page, they must decide which (usually embedded) hyperlinks they want to navigate, and in which order they will do that. Efficient navigation, usually defined as the ability to stay in a sequence of pages that are relevant for the readers' goal, is predictive of readers' success in several advanced digital reading tasks including studying for a long course (Puntambekar, & Goldstein, 2007; Sullivan & Puntambekar, 2015), reading for comprehension (Salmerón, Cañas, Kintsch, & Fajardo, 2005; Salmerón & García, 2011), reading to prepare a summary (Richter,

Naumann, & Noller, 2003; Naumann, Richter, Flender, Christmann, & Groeben, 2007), and performing a science inquiry task (Goldman et al., 2012).

How do readers navigate through hyperlinks while constructing meaning from hypertext? A classical approach to answering this question consists of using a multidimensional scaling technique to identify patterns of navigation behavior. In this line, Lawless and Kulikowich (1996, 1998) identified three main navigational groups of students: knowledge seekers, feature explorers and apathetic hypertext users. Knowledge seekers spend most of the reading time on content-related documents, feature explorers do that on the non-textual features of the hypertext (e.g., images, videos, maps). , and apathetic users spend short intervals of time on content-related documents and seem to follow a random reading order. Not surprisingly, knowledge seekers learn more than the other groups.

A different approach to study navigation is to analyze the strategies readers use to select hyperlinks. Prior research has identified two main reading goals followed by hypertext readers: coherence and interest. Readers may decide to select hyperlinks trying to maintain high semantic coherence between the currently read section and the linked page, avoiding big ‘semantic jumps’ between pages that often occur when interest drives navigation. The coherence reading goal is positively related to comprehension of the information conveyed in the hypertext (Salmerón et al., 2005), probably because by navigating between conceptually related sections the reader can simultaneously pay attention to and subsequently integrate both units of information (van den Broek & Kendeou, 2015).

In complex hypertext documents, where dozens of hyperlinks are available, readers using a particular navigation goal (e.g., coherence or interest) have to manage information overload, usually by means of scanning or quick inspection of the material,

with the resulting risk of missing relevant information (Cromley & Azevedo, 2009). As recent research has shown, comprehension of the hypertext by readers who scan a lot is inadequate (Salmerón, Naumann, García & Fajardo, in press).

Whereas most previous research has focused on textual navigation, recent studies provide new insights about how readers navigate through mostly visual environments, which allow the user to manipulate the presentation of the information. In this line, Kornmann et al. (2016) found that the more readers adjust the perspective of the information to the task demands, the more they learn.

In summary, navigation is essential for digital reading because it can either support or hinder comprehension and integration of information.

1.2. Navigation: Individual differences

Previous studies have identified key individual differences in the acquisition and efficient use of navigation. From a developmental perspective, the ability to identify relevant web pages from SERPs has achieved an adult level already at upper secondary school. Younger students (e.g., grades 5 to 7), however, base their selections or ratings more on superficial cues such as highlighted keywords than on the underlying semantic information contained in the search result descriptions (Keil & Kominsky, 2013; Rouet et al., 2011). Once adult-level performance is achieved, several cognitive factors contribute to mastering navigation, such as reading skills, working memory, and epistemic beliefs. Reading comprehension is usually defined as the ability to fluently perform several aspects of text processing, such as idea identification, inference generation, or macro-level elaboration (Kintsch, 1998). Those skills facilitate the selection of relevant search results based on the content rather than on superficial keywords (Rouet et al., 2011). In addition, skills to comprehend single-texts (e.g. ability

to decode and to make inferences) support the location of relevant information in digital texts without hyperlinks (Vidal-Abarcal, Mañá, & Gil, 2010), as well as in hypertexts (Coiro, 2011; Naumann, Richter, Christmann, & Groeben, 2008). Students with good single-text comprehension skills are not only better at navigating using a coherence goal (Salmerón & García, 2011), they are also less distracted by misleading cues such as irrelevant word matching between the task goal and the hyperlink tag (Salmerón, Cerdán, & Naumann, 2015).

Another relevant factor is working memory (WM), a cognitive processing resource of limited capacity that involves the simultaneous storage and manipulation of verbal or visuospatial information during cognitive activity (e.g., Baddeley, 2012). Greater visuospatial WM capacity and ability to mentally process visuospatial information are related to efficient navigation, such as spending more time on exploring and comparing the contents of the hypermedia environment from various perspectives and less time with the processing of irrelevant contents (Juvina & van Oostendorp, 2008; Kornmann et al., 2016). Students may need some training on navigation before the effect of visuospatial WM takes place (Naumann et al., 2008). Overall, results suggest that efficient navigation across pages demands that readers process not only the semantic relations between pages, as evidenced by the role of reading skills on navigation, but also the spatial relations between pages and between the sections on a particular page. There is less consensus regarding the role of two other factors on navigation: prior knowledge and epistemic beliefs. Studies looking at web page selection have shown that domain experts are more successful in locating relevant web pages than non-experts (White, Dumais, & Teevan, 2009). Research also suggests that a lack of domain expertise may be compensated for with expertise on search skills (Vibert et al., 2009). Laypersons with high domain knowledge tend to scrutinize search results

more thoroughly before selecting than students with less knowledge (MaKinster, Beghetto, & Plucker, 2002; Kammerer & Gerjets, 2013). Studies looking at navigation across web pages, however, indicate that readers with high prior knowledge do not necessarily navigate in a more efficient manner than those with low prior knowledge (Lawless, Mills, & Brown, 2002; Sullivan, Gnesdilow, & Puntambekar, 2011; Sullivan, & Puntambekar, 2015), probably due to overconfidence in their understanding. To prevent this, the task could explicitly demand navigation in a coherent way. In such task, students with higher domain knowledge navigate in a more coherent sequence (Salmerón et al., 2006). As for the role of epistemic beliefs, the belief that the internet in general is a reliable knowledge resource is related to increased selection of objective (i.e., scholarly, factual) search results and increased time spent on such websites (Kammerer & Gerjets, 2012; Kammerer, Amann, & Gerjets, 2015). However, those findings were not replicated in a different study (Kammerer, Bråten, Gerjets, & Strømsø, 2013). Regarding navigation across pages, research indicates that more 'sophisticated' beliefs that knowledge is complex are related to processing more pages, whereas more 'naïve' beliefs that knowledge is simple are related to spending more time on single pages (Pieschl, Stahl, & Bromme, 2008). Again, those patterns have not been replicated in other studies (Bendixen, & Hartley, 2003). To conclude, further research is needed to clarify the role of prior knowledge and epistemic beliefs in the selection of search results and navigation across web pages.

1.3. Navigation: design influences

1.3.1. Design influences in the selection of web pages

Currently most search engines display results as a list. This format has a strong influence on readers' selection of pages, with readers visually inspecting and selecting mostly the top 2-3 results (Pan et al., 2007). Although a list interface simplifies and thus

supports the selection of web pages, this may come at a price, especially if the results on the top of the list are not totally relevant or trustworthy. Other search engine presentation formats have been proposed to cope with such risks. For example, in a grid interface the impact of the position of the search results on the selection is substantially reduced, as compared to a list interface (Kammerer & Gerjets, 2014a). Other presentation formats aim to provide additional information not available in lists. Overview interfaces display the results in groups and tag them according to different criteria, such as the source type (Kammerer & Gerjets, 2012), the rhetorical relations between web pages (Salmerón, Gil, Bråten, & Strømsø, 2010), or a tag cloud with important terms associated with the search (Gwizdka, 2009). Again, in such interfaces the effects of result position on the list are reduced, which suggests that readers are being more careful in their selection.

1.3.2. Design influences in the navigation across web pages

Design characteristics also facilitate navigation, i.e., the selection of relevant links and prevent access to irrelevant ones. Adaptive navigation support is used to modify hypertext documents to cope with students' learning challenges (Brusilovsky, 2001). For example, the ScentTrail system (Olston & Chi, 2003) aims to enhance the salience of hyperlinks on a page that may be relevant for the user's goals. The system calculates the semantic relation between users' goals and the available links, and subsequently increases the size of links rated as more relevant for the students' task. A study on a complex commercial website revealed that users are faster in locating different information on the site when using the ScentTrail system as compared to a non-modified version of the site (Olston & Chi, 2003).

Hyperlinked structures may be particularly challenging to navigate if they are not visible to readers, and if they overload their processing capacities. From a design

perspective, a way to prevent comprehension problems due to navigation load is to provide navigation guidance such as organizational overviews. Overviews are graphical representations of the hypertext structure, which depict the available documents or nodes and their relations. Readers can use the overview as a mental schema in which to incorporate the information distributed across the different hypertext nodes, which may facilitate their navigation and comprehension. Overviews that convey the semantic organization of the hypertext information and follow a hierarchical structure support comprehension to a greater extent than non-semantic or networked organizations, such as spatial arrangements of nodes or alphabetical lists (for a review, see Amadieu & Salmerón, 2014).

By navigating, readers establish links between potentially related information sources. However, establishing those links does not necessarily imply that readers are constructing a coherent mental representation of relevant documents. In order to do that, readers also need to integrate content, both from the different information sources and from what they already know about the issue in question.

2. Integration

Learners' comprehension of information presented on different digital information resources will partly rely on their ability to integrate information across various kinds of representations. Such integration often is a demanding task. In Kintsch's (1998) influential construction-integration (CI) model such processes are described in detail, emphasizing how readers construct a mental representation of a text based on its lexical and syntactic surface and make inferences based on the text's coherently related parts. Integration, thus, requires that reader's prior knowledge is connected to the new information such that the two become associated in memory. While a reader processes a text, the mental representation of that text continually develops as information across

the text is integrated with what the reader already knows, from earlier sections of a text and from his or her semantic background knowledge. The text's author will normally facilitate such processes of integration by introducing different kinds of cues like verbal organizers, indications of semantic relations, or by reminding the reader of background knowledge necessary for comprehension (Rouet, 2006). A more demanding situation occurs when readers have to integrate information across several information resources, often containing various kinds of representations.

2.1. Integration: description of the competence

2.1.1. How readers integrate information from different web pages

In real life, readers are regularly confronted by a number of information sources representing different perspectives or contradicting information on the same issue. If a reader's goal is to understand more about that issue and not only search for some factual information, the reading process will involve the often challenging task of integrating information across multiple sources. When readers approach the web they also will meet diverse types of information, including mixed genres and mixed modalities, and thus will have to deal with the sometimes overwhelming task of constructing a coherent understanding from a multitude of different representations of an issue or situation. One of the main characteristics of online text comprehension is that the readers also are "authors" of an integrated mental representation by selecting and integrating different pieces of information (Afflerbach & Cho, 2009).

Whereas the author of a single text normally aims to present a coherent story or description, the task of constructing coherence is left to the reader when multiple information sources are involved. Content across multiple information sources may be partially overlapping, partially unique, and partially contradictory. When reading on the web, an important task is to identify and select information that should be included in

the process of constructing an integrated representation of the material. If information partially overlap across documents, readers' representation of that content may be more or less automatically updated as they proceed through the documents (Kurby, Britt & Magliano, 2005; van Oostendorp, 2002), whereas integration of unique or contradictory information may require more strategic inferential processes from the reader (Bråten, Anmarkrud, Brandmo & Strømsø, 2014; van den Broek & Kendeou, 2015). Sometimes documents containing overlapping information may also present a need for strategic monitoring of the potential intertextual links. Two web-texts on the same topic may differ in style and partly use dissimilar terminology in referring to the same phenomena. The reader faces the challenge of deciding whether those documents are referring to the same thing and whether documents using the same terminology actually refer to the same thing (Rouet & Britt, 2014). Thus, integration across documents may sometimes require expertise on the topic of interest regarding both rhetorical conventions and terminology.

2.1.2. How readers integrate across online modalities

The demands of integrating information across multiple textual documents often increase when those documents contain not only written information but also spoken or visual information in the form of pictures, graphs, animations, or videos. There are several models (e.g. Mayer, 2005; Schnotz & Bannert, 2003) describing how text and pictorial information are processed through separate channels, with this potentially resulting in a richer and more accessible mental representation than if only one channel is used. Those models also emphasize, however, emphasize that the integration of words and images is a quite demanding process requiring efficient use of cognitive capacity.

Reading on the web may imply that readers attend to more than one window within the same application (or even different applications) and sometimes also

simultaneously to several windows related to different tasks. In addition, it is not uncommon that readers switch between different media, for example between printed text and different digital devices. Whereas a couple of studies indicate that media multitasking does not necessarily affect text comprehension, students' reading times do increase with multitasking (Fox, Rosen, & Crawford, 2009; Subrahmanyam et al., 2013). It has been argued that media multitasking may be a misleading term, as several studies indicate that people do not attend to several media simultaneous but rather *switch* between media. Also, several studies show that such task switching tends to impair learning (Kirschner & van Merriënboer, 2013). For example, Ophir, Nass and Wagner (2009) find that heavy media multitaskers were less inclined to ignore irrelevant information than light media multitaskers. Research on reading in an environment of multiple digital reading devices has so far been limited. Given research from other fields (e.g., Kirschner & van Merriënboer, 2013) on task switching or multitasking, there are reasons to believe that – at least habitual- multitasking decreases comprehension of digital texts. However, more research is needed.

2.2. Integration: individual differences

Preliminary evidence for individual differences in integration comes from studies using as dependent variable success rate in a set of digital reading tasks, some of which demand readers to integrate information located in different hypertext nodes. From this approach basic computer skills and reading skills emerge as relevant factors.

Basic computer skills include actions of accessing, saving, and communicating information using an interface. Individual differences partly explain the success in digital reading tasks, even after controlling for the effect of other factors such as reading skills or navigation efficiency (Goldhammer, Naumann & Keßel, 2013; Hahnel, Goldhammer, Naumann & Kröhne, 2016). Similarly, there is evidence revealing that

reading skills improve digital reading in several tasks, including reading to comprehend (Coiro, 2011; Naumann et al., 2008; Salmerón & García, 2011; Sung, Wu, Chen & Chang, 2015), and question-answering tasks (Naumann & Salmerón, 2016; Salmerón et al., 2015; Salmerón et al., in press; Sung et al., 2015). Although evidence suggest that basic computer and reading skills positively predict success in digital reading tasks, some of which demand integration, the specific involvement of such skills on integration tasks is is not yet clear.

Recent efforts to identify factors specifically affecting integration processes have shown that relevant prior knowledge is necessary to integrate and solve inconsistencies between information in different texts. Beker, Jolles, Lorch, & van den Broek (2016) demonstrated how information from one text can help solve an inconsistency in the other. That is, relevant information from a previously read text was spontaneously activated when readers encountered the inconsistency, which indicates intertextual integration. Considering the multitude of information resources on the web, intertextual integration may be more challenging in more ecological valid settings. According to a research review on hypertext reading, this may at least be the case for low knowledge readers (DeStefano & LeFevre, 2007).Those readers seem to benefit from more structure and fewer choices, whereas the lack of such conditions does not affect high knowledge readers' comprehension. Additionally, several studies indicate that readers' working memory may affect their capacity to integrate information across information sources (DeStefano & LeFevre, 2007).

2.3. Integration: design influences

As we discussed above, integration of textual and visual information will improve readers' comprehension. But the benefits of multimedia learning seem to rely on a careful design of the learning material (Paas & Sweller, 2014), whereas the more or

less random mix of modalities presented on the web increases the cognitive load of readers attempting to synthesize information across different sites. One of Mayer's design principles (Mayer, 2005) is, for example, to eliminate external distracters such as extraneous words, pictures, and sounds (Issa et al., 2011). While searching for information resources on the web such distracters seem hard to avoid. Thus, dealing with multiple forms of representations on the web requires more cognitive effort than processing information in a well-designed multimedia learning environment. The multimedia effect, assumed to positively affect readers' integration of information, may turn out to hamper integration when readers attempt to integrate information across more or less random information resources on the Web.

Does the nature of the reading material impact readers' integration of information across texts? While reading printed texts skilled readers make connections between different parts of the text in order to capture the main ideas. The nature of digital texts presents several new challenges to readers' efforts to generate both intra- and intertextual connections. A number of features of different digital devices hypothetically could affect readers' integration of information within and across texts,. These features include screen size, design of browser, navigation of menus, scrolling, dynamic links and images, and the need to open and close windows and tabs. Studies comparing reading on paper versus reading on screen show mixed results (e.g. Mangen, Walgermo & Brønnick, 2013; Margolin, Driscoll, Toland, & Kegler, 2013; Singer & Alexander, in press), and often such comparisons focus on the reading of one single linear text presented either on screen or as printed. More features of the ergonomics of the reading situation need to be researched. Prior studies on reading from screens indicate that such features as line length, number of columns, and the size of screens affects reading time and, in some studies, also comprehension, though results are mixed

(Dyson, 2004). Results from a study by Sanchez and Wiley (2009) showed that scrolling negatively affected readers' text comprehension, and that readers who had lower working memory capacity were most challenged by the scrolling procedure. However, some researchers propose that scrolling is not a problem provided that line length is moderate and that there is additional space between paragraphs (Dyson, 2005). Thus, the length of the texts may interact with other features of the text and in some cases affect readers' integration of information across windows.

Results from some studies indicate that browser design is related to readers' processing of digital texts (e.g. Olive, Rouet, Francois & Zampa, 2008; Wiley, 2001). Specifically, whether the browser design facilitates integration across texts affects the reading process and comprehension. For example, Wiley (2001) tested if a two-window browser afforded learning from multiple web-sites better than a single-window browser. The results showed that a two-window browser supports processes of integration across the web-sites more than a single-window browser does, but only when the reading task required such integration.

In summary, interface design influences integration of digital information. Careful design is necessary to maximize readers' comprehension and integration. Additionally, readers need to consider what textual information to include, and what to exclude, in the integration processes. Thus, they must continuously evaluate new information according to certain criteria.

3. Evaluation

The internet is a marketplace of opinions where traditional gatekeepers of trustworthiness are missing. As a consequence, readers are required to evaluate information in terms of relevance and trustworthiness. In an optimal case, this will help readers make appropriate metacognitive decisions such as whether or not to process the

contents of a website more deeply or to decide which knowledge claims to accept as valid in a discussion in social media.

3.1. Evaluation: description of the competence

3.1.1. How readers evaluate information from web pages

Critically assessing the relevance and determining the trustworthiness of contents and sources are important cognitive processes in the stage of browsing through web pages. What looks promising in the brief description of a SERP may turn out to be of little relevance once full access to the document is provided. Similarly, access to more comprehensive author information provided on an 'about us' page may add to a reader's perception of the extent to which the information can be trusted. Each of the two factors relevance and trustworthiness separately and the two in concert thus contribute to a reader's perception of the relative usefulness of a website against the background of the reader's goals.

In their content-source-integration model, Stadtler and Bromme (2014) distinguish between two ways of accomplishing decisions about the relative trustworthiness of knowledge claims. Readers can either make first-hand decisions by comparing what they read against what they believe to be true based on their world knowledge (i.e., they answer the question "what is true?"), or they can make second-hand decisions by scrutinizing source information (i.e., answering the question "whom to believe?"). When readers process unfamiliar contents, in particular, their prior knowledge may be too fragmentary to make truly informed first-hand decisions. In this case, second-hand decision, i.e. evaluating sources may be a better way to attain trustworthiness judgments.

Digital readers often draw on their prior knowledge when judging the trustworthiness of information, even when their prior knowledge is fragmentary (Kiili,

Laurinen & Marttunen, 2008; Scharrer, Bromme, Britt & Stadtler, 2012). This reliance is particularly high when scientific information is presented in a seemingly easy and popularized way, that is, without the use of specialist language as it is the case in many web pages (Scharrer, Britt, Stadtler, & Bromme, 2013; Scharrer et al., 2012; Scharrer, Stadtler, & Bromme, 2014).).

Digital readers seldomly use source information to make trustworthiness judgments and – if they do – tend to rely on rather superficial cues, such as professionally looking design (e.g., Brem, Russell, & Weems, 2001; Eastin, Yang, & Nathanson, 2006; Halverson, Siegel, & Freyermuth, 2010; Gerjets, Kammerer, & Werner, 2011; Strømsø, Bråten, Britt, & Ferguson, 2013). This behavior is not due to a lack of adequate knowledge because many readers, even from secondary grades, are able to name or to consider adequate criteria against which to evaluate online information. These include source characteristics, such as the expertise or intentions of a source, the date of publication, and the extent to which information accuracy is assured through editorial quality checks (Kammerer & Gerjets, 2014b; Keck, Kammerer, & Starauschek, 2015; Paul, Macedo-Rouet, Stadtler, & Rouet, 2016). However, students often fail to apply these criteria when facing the complexity of reading online (Walraven, Brand-Gruwel, & Boshuizen, 2009).

3.1.2. How readers evaluate information in social media

People read on the internet not only to acquire knowledge. The rise of social networks has increased the extent to which people read to solve personal problems or to look for emotional support (Gazan, 2010)Before the internet these uses were mostly limited to face-to-face interactions. For example, Kim and Oh (2009) analyzed the characteristics of “best answers” in Yahoo! Answers, a social question-answering forum in which users post questions and others submit answers. Users posting the questions

tend to rate as “best answers” those that include statements of emotional support (e.g. “Your words really helped”), agreement (e.g., “Finally, someone who agrees with me”), and experience (e.g. “Thanks to the other person who posted the big list of symptoms”).

A major challenge of reading information from social media is that the quality and credibility of information is highly variable, and readers have to handle this problem without the credibility cues available in face-to-face interactions. When two authors provide conflicting information in social networks, such as web forums on daily life topics (Salmerón, Macedo-Rouet, & Rouet, 2016) and blogs on scientific controversies (Winter & Krämer, 2012), readers prefer messages that were written by experts rather than by laypersons. Such preference interacts with the type of evidence provided by the author and with the reader’s developmental or educational level. Primary school students are more likely to recommend expert messages referring to personal experience whereas undergraduates are more likely to prefer expert messages referring to another information resource (e.g., a hospital web page) in support of author claims (Salmerón et al., 2016). The appeal to personal experience may be more relevant when readers seek emotional support from social networks, such as when reading about risk-related topics (Betsch, Ulshöfer, Renkewitz, & Betsch, 2011).

In summary, users of social media tend to be cautious when it comes to accepting information from others. They may rely on unreliable cues, such as personal experience, when they read about risk-related topics such as vaccinations.

3.2. Evaluation: individual differences

There are important individual differences in the acquisition and use of evaluation. existing small number of studies on evaluation from a developmental perspective indicate that this skill changes during middle and high school in qualitative

rather than quantitative ways. Eastin et al. (2006) found that eight- to eleven-years-old children evaluated a website lacking source description as more credible than the same page with author credentials. Salmerón et al. (2016) found that fifth and sixth grade students recommended more often forum comments that included personal experiences as support, whereas undergraduate students favored the messages backed by documentary evidence.

For adult students, prior knowledge, self-efficacy, and epistemic beliefs are key factors in their evaluation processes. Readers' trustworthiness judgments seem to be influenced by their level of prior knowledge. Readers lacking prior topic knowledge are particularly likely to trust clearly false information when it was presented in professional layout (Fogg et al., 2003; Lucassen, Muilwijk, Noordzij, & Schraagen, 2013). Notwithstanding the widespread neglect of source information, many readers exhibit a high degree of trust in their evaluation competencies (Ivanitskaya, O'Boyle, & Casey, 2006; Kuiper et al., 2008). Ivanitskaya et al. (2006) report that in a sample of university undergraduates the majority of students considered their research skills good or even excellent, whereas many of them were unable to judge the trustworthiness of health-related websites and did not differentiate between various information sources. Adult readers are better calibrated: In a study with in-service teachers, Andreassen and Bråten (2012) found that readers' self-efficacy to evaluate sources predicted their use of relevant source features when evaluating the trustworthiness of web sources. The poor calibration of younger readers poses a problem to educators who want to train students' evaluation skills because students likely lack the motivation to work on their evaluation skills if they already consider themselves as good or excellent. Finally, another important reader characteristic that has emerged from the literature are individuals' epistemic beliefs (e.g., Barzilai, Tzadok, & Eshet-Alkalai, 2015; Kammerer et al., 2015;

Kammerer et al., 2013; Mason, Pluchino, & Ariasi, 2014). For instance, Kammerer et al. (2015) found that the more participants believed that internet-based knowledge claims need to be critically evaluated, the more time they spent on reliable web pages from official institutions and the less time they spent on subjective web pages such as forum pages and commercial web pages.

3.3.Evaluation: design influences

According to the content-source-integration model (Stadtler & Bromme, 2014) presented above, one can distinguish between evaluation based on content and evaluation based on source features (such as metadata on the text such as who wrote it, where and when it was published, or text genre). The design of a digital text also presents information about the text and, thus, may affect readers' evaluation. This was clearly demonstrated when Fogg et al. (2003) had people comment about web pages' credibility. Data were collected across a number of different sites on topics such as finance, health, news, and travel. The most frequently referred evaluation categories were visual design (e.g., professional looking) and structure of the sites' information (e.g., well organized). The potential impact web pages' visual design has on readers' evaluation was confirmed in a study by Robins and Holmes (2008), which showed that web pages perceived as having a professional graphic design were considered more credible than those without such designs. Likewise, Flanagin and Metzger (2007) found that web pages' genre familiarity (e.g. news organizations, e-commerce) affected people's evaluation of site credibility. Of course, the multitude of genres and genre-mixes on the internet present a challenge when readers depend on their familiarity with genres to evaluate digital texts.

Results from the above studies indicate that the design of digital texts is an important factor in readers' decision on whether to read a digital text critically or not.

Results from the Robin and Holmes (2008) study showed that readers only spent 2-3 seconds on a web page before responding with a credibility judgment. Thus, participants apparently have evaluated the digital text before they had time to engage with the content or to reflect carefully on other adequate source features. It is interesting to note that participants in this study were graduate students in library and information science. This suggests that educational initiatives targeting critical reading of digital texts may be helpful to students at all levels.

A way to stimulate readers to attend to and evaluate source information more critically is by presenting contradictions between web pages (e.g., Strømsø, Bråten, Britt, & Ferguson, 2013; Barzilai & Eshet-Alkalai, 2015; Kammerer & Gerjets, 2014b; Kammerer, Kalbfell, & Gerjets, 2016). Teachers could take advantage of this effect in their design of online reading tasks such as Webquests (Segers & Verhoeven, 2009) by incorporating web pages with clear contradictory claims.

4. Methodologies for the study of digital reading

To capture the complexity of the different competencies of digital reading (navigation, integration, and evaluation) researchers need to use advanced methods that allow to track students' text processing while reading (eye-tracking, log-files, and verbal protocols). In addition, research uses different methods to capture how that processing reflects in actual comprehension and learning.

4.1. Eye tracking

Eye-tracking methodology continuously tracks the position of the eyes while they move across visual stimuli, such as text or pictures presented on web pages. Thus, eye tracking allows one to determine whether, for how long, and in which order individuals pay attention to certain information (cf. Scheiter & van Gog, 2009). Based on the assumption that what is being fixated by the eyes is being processed in the mind (eye-

mind-assumption; Just & Carpenter, 1980), eye-tracking data is a strong indicator for individuals' moment-by-moment cognitive processing (cf. Rayner, 2009). It provides insights into cognitive processes at a very fine-grained level, which, for instance, allows differentiating between initial reading and re-reading (cf. Hyönä, Lorch, & Rinck, 2003). It also provides data concerning cognitive processes that do not lead to overt actions (e.g., when deciding not to click on a certain hyperlink). Moreover, it seems highly suited to unravel quick and automated or unconscious cognitive processes, which are difficult to express verbally (cf. Scheiter & van Gog, 2009). However, in order to correctly interpret eye-tracking data (e.g., whether longer fixation times on an object indicate increased interest or rather comprehension difficulties), combinations with other type of data, such as verbal protocols or log-files (see below) are extremely helpful.

4.2. Log files

Navigation is most often measured in the literature through readers' log files, which record traces of their clicks on the hypertext. Log-file indexes can consider visits to particular web pages (e.g., number of visits, reading time, pages relevant for students' goals) and capture some characteristics of the navigation sequence (e.g., percentage of transitions between semantically related web pages) (Naumann, 2008). In most studies navigation is assessed by focusing on the characteristics of the web pages visited but not looking at the specific processes that motivated particular navigation moves. This limits the power of the literature to inform psychological models of digital reading because an identical index (e.g. click on a page relevant for the students' goal) may reflect verydifferent underlying processes (e.g. heuristic or elaborated processing). Winne (2010) has argued that a way to solve this problem is to include in the studies theoretically motivated hyperlinks, so that a selection of a particular hyperlink can be

linked easily to a unique theoretical explanation (for a recent example of this approach see Salmerón et al., 2015).

4.3. Verbal protocols

Verbal protocols have been a common method to capture processes of digital reading (e.g. Anmarkrud, McCrudden, Bråten & Strømsø, 2013; Goldman et al., 2012; Greene, Yu, & Copeland, 2014). Ericsson and Simon (1993) have described verbal protocols as one valid way to study cognitive processes, provided that the materials and task are sufficiently challenging. Pressley and Afflerbach (1995) reviewed the use of verbal protocols in studies on reading and showed that such protocols also could be appropriate for the study of text comprehension. The method, also referred to as think-aloud method, asks subjects to report their thinking as they read. Verbalizations are recorded, transcribed, and coded. It has been suggested that thinking aloud while reading may affect task performance and that it prompts reading aloud. However, a number of studies indicate that thinking aloud does not necessarily affect peoples' cognitive processing, provided that researchers follow specific procedures emphasizing that subjects should verbalize whatever comes into their mind and not respond to specific questions (Fox, Ericsson, & Best, 2010; Hertzum, Hansen, & Andersen, 2009).

4.4 Evaluation tasks

Evaluation tasks are most often used in order to assess readers' judgments about a document's credibility. These tasks come in a number of different formats, for example by asking readers to rank websites according to reliability and next ask them to justify the ranking (Wiley et al. 2009). Justifications are coded, with coding schemes typically including justifications both by content (e.g. evidence, explanations, arguments) and by source (e.g. author, affiliation, date of publication). Another approach is to ask participants to rate websites on a scale according to trustworthiness,

expertise, and convincingness of information, with those scores together representing websites credibility (van Strien, Kammerer, Brand-Gruvel, & Boshuizen, 2016). Rating of trustworthiness has also been used in order to investigate how participants emphasize different kinds of source features in making such ratings, with students instructed to rate the importance of different source features (e.g. layout, URL address, or author) when evaluating how trustworthy websites were (Andreassen & Bråten, 2013). Whereas the above studies accentuate measures of different aspects of a websites' credibility, Walraven, Brand-Gruvel, and Boshuizen (2013) emphasize both credibility and relevance. They instructed students to select from SERPs websites that were appropriate to certain topics and then to indicate on what information in the SERP they had based their decisions. Thus, criteria for both relevance and reliability were scored. Likewise, students were presented with a set of websites and asked which they would use given a specific task, and then highlight on which features they based their decision. Although evaluation tasks are most often used to measure students judgments concerning aspects of credibility, they could also be used to investigate other criteria such as relevance.

4.5 Memory and comprehension tasks

Measures of readers' memory for or comprehension of digital information do not essentially differ from reading measures related to printed texts. For example, memory for factual knowledge from digital sources has been assessed by having participants verifying whether statements are true or false (e.g. Amadieu, van Gog, Paas, Tricot, & Mariné, 2009; Mason et al., 2014) or by multiple-choice tests (e.g. Stadtler & Bromme, 2007). Comprehension of digital documents has frequently been measured by the use of short open questions (e.g. Stadtler & Bromme, 2007; Walraven et al., 2013) or student essays (e.g. Anmarkrud et al., 2013; Mason et al., 2014; van Strien et al., 2016). The essays are scored according to criteria related to the writing task and the focus of the

study. For example, to investigate readers' attitude strength and biased information processing van Strien et al. (2016) scored arguments according to whether they were attitude-consistent/inconsistent.. In studies focusing on studies readers' multiple documents comprehension student essays typically are scored according to whether readers are able to incorporate positions from different information sources in their understanding of a set of websites. For example, Mason, Junyent, and Tornatora (2014) used this method to investigate whether participants identified corroborating evidence or contradictions across sources, whereas Anmarkrud et al. (2013) used it to code argumentative reasoning according to if and how opposing positions from the information sources were used in essays.

Amadieu et al. (2009) used another kind of measure of intertextual comprehension. They included the same kind of sentence verification test as described above to test memory for factual information, but in order to answer correctly students needed a conceptual understanding based on at least two information nodes in a hypertext. Given that coding of essays is a rather time-consuming process, sentence verification tests may be an alternative when measuring integration across digital information sources. However, to develop valid and reliable sentence verification tests also is a demanding process.

5. Discussion and future directions

In the previous sections, we have reviewed the current state of knowledge about the three main competences involved in the comprehension of digital texts. Although there is substantial evidence regarding how readers navigate, integrate, and evaluate information from digital texts, there are still unresolved issues such as how those competencies interact and how they are acquired during adolescence. In the remainder

of this chapter, we discuss some of these issues, and how new methodologies could help to shed further light on digital reading.

As our review illustrates, most previous research has studied the competencies navigation, integration, and evaluation in isolation. During actual reading students usually need to coordinate all three competencies, depending on task demands. For example, while reading to complete a class assignment, students need to navigate through a hypertext to a page with potentially relevant information for the assignment. Once they have located such a page, they may need to evaluate the quality of the claims on the page before deciding if those claims should be integrated together with the information previously found in other sources. Failure implementing any of such competencies may result in a failed assignment. The question arises whether these three competencies are independent or form a single general skill. A recent study by Hahnel et al. (2016) suggests that relations between skills are not obvious. They analyzed teenagers' ability to select web pages (using a test to select web pages from SERPs) and to navigate across hypertext. Although the ability to select web pages was positively correlated with efficient navigation, this correlation disappeared once single text comprehension skills were accounted for. Thus, it is possible that teenagers develop each of the three competencies, at least to certain degree, as separate skills.

A crucial task for future research will be to better understand how individuals acquire the three skills - both inside and outside of formal education. One factor that may promote skill acquisition is extended practice with digital texts. Recent evidence suggests that this relation is not straightforward, and may vary according to the demands of the tasks that students pursue when they engage with digital texts. Specifically, Naumann (2015) has reported that a high exposure to information tasks, such as searching the Web for particular information, is positively associated with

teenagers' efficient navigation and comprehension in digital reading tasks. The opposite effect was found between the time expended on social tasks, such as using e-mail or chatting, and comprehension. A different aspect related to the development is how competencies involved in digital comprehension interact with single text comprehension. Exposure to social tasks in digital texts also has been identified as a negative predictor of single text comprehension (Duncan, McGeown, Griffiths, Stothard, & Dobai, 2015). In summary, there is a potential risk that time invested in social activities in digital texts may prevent students from being exposed to more complex academic language, which is necessary to develop their general deep comprehension skills. Because this evidence comes from correlational studies, a note of caution is necessary before proposing causal connections between the acquisition of digital text competencies and its effects on single text comprehension skills. Future research should also determine if the effects of exposure on the acquisition follow different patterns for the three competencies of digital reading identified in the chapter.

Intense exposure to digital texts alone obviously is not enough to let individuals become proficient comprehenders of digital information. This is why, recently, an increasing number of attempts to promote the skills of navigation, integration, and evaluation has been presented (for an overview, see Stadtler, Bromme, & Rouet, in press). These range from parsimonious educational scaffolds (e.g., prompting procedures) to more comprehensive workshop-like interventions, and have been tailored to groups of primary students (e.g., Macedo-Rouet, Braasch, Britt, & Rouet, 2013; Zhang & Duke, 2011), secondary students (e.g., Gerjets & Hellenthal-Schorr, 2008; Kammerer, & Werner, 2011; Mason et al., 2014; Stadtler, Paul, Globoschütz, & Bromme, 2015), and adults (e.g., Kammerer, Amann, & Gerjets, 2015; Stadtler & Bromme, 2007; Stadtler, Scharrer, Macedo-Rouet, Rouet, & Bromme, 2016; Wiley et

al., 2009). The available empirical evidence suggests that it is indeed possible to promote the skills of navigation, integration, and evaluation, although reported effects are often limited in magnitude and restricted to short-term behavior changes. Future research will have to demonstrate to what extent the available interventions facilitate sustainable change in the ways learners approach digital texts. Another limitation of the existent evaluation studies is that the instruction has usually been provided by the researchers themselves. Studies of this kind are certainly a valuable starting point, but they do not inform us whether similar learning gains would be obtained when instruction is provided by teachers and under regular classroom conditions. Against this background, future research needs to focus to a greater extent on training teachers how to incorporate the promotion of navigation, integration, and evaluation skills into their regular curriculum.

Finally, future research may see an expansion of the toolbox of methodologies for investigating the processes described in this chapter. A particularly interesting and potentially powerful set of methodologies consists of neuro-imaging techniques. Although the application of techniques such as fMRI, EEG/ERP, or MEG is still in development even for the study of comprehension processes in traditional, single text reading situations they have the potential to reveal details of the time lines of the various component processes outlined above as well as of the interactions between neural structures (for a review see Price, 2012). Application of these methods has allowed important advances in our understanding of integration and evaluation processes during reading of sentence pairs, and is likely to do the same in the future for our understanding of comprehension processes in digital reading.

Comprehension of digital texts is a unique combination of navigation, integration, and evaluation of information. In this chapter we summarized our current

knowledge about these competencies, and we emphasized the need to focus on their interrelations. We expect that our review will open up interesting new avenues for research.

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