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Reading on Paper and Digitally: What the Past Decades of Empirical Research Reveal

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This systematic literature review was undertaken primarily to examine the role that print and digitally mediums play in text comprehension. Overall, results suggest that medium plays an influential role under certain text or task conditions or for certain readers. Additional goals were to identify how researchers defined and measured comprehension, and the various trends that have emerged over the past 25 years, since Dillon's review. Analysis showed that relatively few researchers defined either reading or digital reading, and that the majority of studies relied on researcher-developed measures. Three types of trends were identified in this body of work: incremental (significant increase; e.g., number of studies conducted, variety of digital devices used), stationary (relative stability; e.g., research setting, chose of participants), and iterative (wide fluctuation; e.g., text length, text manipulations). The review concludes by considering the significance of these findings for future empirical research on reading in print or digital mediums.

Keywords: reading, comprehension, digital reading, medium

> Nobody is going to sit down and read a novel on a twitchy little screen. Ever.
>
> —Annie Proulx, fiction writer (1994)

Although this may come as a surprise to Proulx (1994), it would appear that the world is digitally at one's fingertips. Open 24 hours a day, 365 days a year, the digital world has become a one-stop text source, be it for news, recreational reading, or information sharing via Facebook, blogs, or tweets (DiMaggio & Hargittai, 2001). Humans live in a society that is constantly plugged into the Internet whether by computer or by handheld device. Although it goes without saying that the digital age has come with many benefits, including rapid and expanded access to information and untold networking capabilities (Castells, 2011; Labrecque, vor dem Esche, Mathwick, Novak, & Hofacker, 2013; Usluel, 2016), questions remain about the implications of such digital access and the many digital devices

(e.g., computers, tablets, and smartphones) that allow for that access for reading and learning from text (Underwood, Underwood, & Farrington-Flint, 2015).

More specifically, the use of digital devices as reading tools has garnered increased importance as schools move to paperless classrooms across the globe (Giebelhausen, 2015; Shishkovskaya, Sokolova, & Chernaya, 2015). These paperless classrooms allow the reader to alter the size of the text, highlight important passages, and search related terms outside of the text with the click of a button. Not surprisingly in light of these developments, 97% of students by 2009 had access to a computer in their classroom (National Center for Education Statistics, 2013). Moreover, even outside the classroom context, more and more individuals are engaged in online reading. For instance, and contrary to Proulx's (1994) prognostication, Zickuhr, Rainie, Purcell, Madden, and Brenner (2012) found that 43% of Americans and 48% of those between the ages of 18 and 29 read lengthy texts, such as newspapers or books, digitally—a number expected to increase exponentially (Stephens, 2014). These figures raise the fundamental question of how the use of such digital reading materials might potentially alter perceptions of what it means to read and the comprehension that results, for better or for worse.

In fact, such a fundamental question has been posed in years past. For example, in 1992, Dillon conducted a review of the literature intended to examine differences that might exist when reading from a printed source versus an electronic source. To our knowledge, this was one of the only reviews that examined print reading vis-à-vis digital reading. However, although that review can serve as a starting point in the conversation about print and digital reading, a more contemporary analysis of the extant literature is clearly warranted. We see this review as warranted not solely because of any shortcomings that might be ascribed to Dillon's review but also because much has changed technologically since the early 1990s.

Moreover, as we suggested at the outset, all signs point to a growing presence of digital reading in the lives of students and their teachers. One reason for our conviction regarding this trend is that there are now a plethora of devices to employ when reading digitally, from computers to other mobile devices such as iPads, Kindles, and even smart watches. Thus, in this systematic review, we set out to examine the empirical literature published since 1992—the year of Dillon's review—that pertained to the mediums in which reading occurred (i.e., in print and digitally). Our overarching goals were to more richly describe the state of the research encompassing print and digital reading and to better ascertain how the affordances of print or digital mediums relate to what students understand from those textual encounters.

One justification for this systematic review is the limited understanding of how particular attributes of the learner, the text, or the context might interact with the medium to enhance or inhibit comprehension. The theoretical or empirical models that currently inform research, including this inquiry, deal more with the nature of single-text comprehension (Kintsch, 1988) or with the effects of multimedia within a given text (Mayer, 1997). There are also well-articulated models of learning and performance when multiple texts are implicated (Bråten & Strømsø, 2011; Rouet & Britt, 2011). However, to our knowledge, the medium of text delivery in these single-text or multiple-text models remains underinvestigated as a pertinent factor.

For example, perhaps the most cited model of comprehension is Kintsch's (1988) construction-integration model of comprehension, which serves to explicate how comprehension results from the interaction of the textual content and readers' knowledge and experiences by means of the text base and the situation models, respectively. This model, however, does not consider whether texts are presented in print or digitally. Furthermore, Mayer's (1997, 2011) cognitive theory of multimedia learning (CTML) has been built on decades of empirical research addressing processing demands of texts that incorporate both linguistic and visuographic content. The CTML model outlines 12 principles of text and visual integration, such as the coherence principle or the redundancy principle, intended to guide the design of multimedia materials. Although informative to those invested in multimedia documents, the CTML does not consider the nesting of such materials in print versus digital mediums. Finally, from the emerging models of multiple source use, such as the Multiple Documents-Task-Based Relevance Assessment and content extraction model (Rouet, 2006; Rouet & Britt, 2011), there is a growing awareness that several factors, such as individuals' epistemic beliefs, task directives, or the provocative nature of the topic, influence comprehension. Yet the fact that such multiple documents may be conveyed in print or digitally has not been directly incorporated in emergent models.

Although these well-studied theoretical models can shed light on what occurs when individuals process texts either in print or digitally, they have not addressed questions about when, for whom, and for what purposes one mode of delivery (i.e., print or digital) might prove more beneficial than another. As articulated by Jenkins (1974) in his tetrahedral model of learning, and as argued more contemporarily by Alexander, Schallert, and Reynolds (2009), researchers concerned with learning and performance must consider the interactions among the *who*, *what*, and *where* dimensions of a given situation. Thus, this systematic review was undertaken to explore such dimensions with the goal of informing ensuing efforts to construct an evidence-based model of reading in print and digitally.

The specific research questions that guided this study were as follows:

Research Question 1: Within the literature addressing both print *and* digital reading, how has comprehension been defined?

Although the conceptions of print and digital reading articulated by researchers were empirical questions we sought to investigate, our literature search was informed by a conceptualization of reading reflected in the Reading Framework for the National Assessment of Educational Progress (NAEP; National Assessment Governing Board [NAGB], 2008). Specifically, for the purpose of this systematic review, we broadly defined reading as the dynamic process of understanding and drawing meaning from written text. We regarded this general conception as relevant whether the process of reading occurred in print or digitally.

There is strong justification for our decision to look expressly at researchers' conceptions of *reading* and *digital reading*. For one, there are those who have decried the lack of conceptual clarity and specificity within the educational

literature (e.g., Alexander & Dochy, 1995; Dinsmore, Alexander, & Loughlin, 2008; Murphy & Alexander, 2000). There is also evidence that even foundational concepts (e.g., knowledge, beliefs, learning, motivation, or self-regulation), including those related to reading (Alexander, Schallert, & Hare, 1991), are often variably, vaguely, and inconsistently defined within the empirical literature. Therefore, as a first step in trying to disentangle the findings of the literature related to reading in print and digitally, it seemed wise to ascertain whether those engaged in that research were operating from an explicit or consistent conceptual base.

Research Question 2: Within the literature addressing both print *and* digital reading, how has comprehension been assessed?

When examining the literature that encompassed the process of reading in both print and digital mediums, we did not wish to overlook the product of those undertakings. In effect, we wanted to determine how participants' comprehension was gauged. Our intention was to chart the levels of comprehension (i.e., locate and recall, integrate and interpret, and critique and evaluate; NAGB, 2008) assessed within each study. This decision was informed by the assumption that medium may play a more influential role when comprehension questions move beyond gist understanding (Singer & Alexander, 2017). In the same vein, we wanted to document the form of those comprehension assessments (e.g., multiple-choice or constructed-response) because the literature suggests that question type may also influence comprehension outcomes (Pearson & Hamm, 2005; Sarroub & Pearson, 1998).

Research Question 3: What trends pertaining to participants, additional (non-comprehension) measures, text types, and digital devices can be identified within the literature on print *and* digital reading?

As part of this systematic review of the literature, we wanted to incorporate a trend analysis. In 1993, Alexander and Knight argued that educational trends, or distinguishable patterns of events in learning and instruction, generally fall into three categories: incremental (upward developments), stationary (little or no change over time), and iterative (repetitive change). Since then, researchers have found these trend designations to be informative (e.g., Alexander, Murphy, & Greene, 2012; Alexander, Murphy, & Woods, 1996; Dumas, Alexander, & Singer, 2015). Thus, for the present analysis, we attempted to ascertain whether there were clear upward, stable, or repetitive trends in the empirical research on reading in print and digitally.

Research Question 4: How do the current trends in the print *and* digital reading literature compare to the trends reported by Dillon in 1992?

Every systematic review requires some starting date in the search for pertinent literature. Despite whatever shortcomings can be ascribed to Dillon's (1992) review of print and digital reading, it does represent a valid starting point for the current investigation and a bases for comparison. Among the shortcomings that

must be acknowledged, Dillon's survey of the literature was neither systematic nor "best-evidence" in form (Slavin, 1986). Consequently, it was not evident how the studies that formed the bases for his findings were chosen. In addition, Dillon's review did not consider the definitions of reading or digital reading that guided researchers' inquiries. This is concerning because without ascertaining researchers' meaning of core constructs, the consistency of reported outcomes remains at issue. Finally, for the most part, Dillon forwarded rather tenuous conclusions regarding print and digital reading that demand reexamination. It was his position that there were too many factors at work to more definitively conclude what differences, if any, manifested across the mediums. Despite these obvious issues, we nonetheless found Dillon's review to be a useful starting point for our own analysis of the research literature pertaining to reading in paper and digitally.

Method

Search Procedures

When establishing our search parameters, we were influenced by formative works that examined the nature of reading comprehension (e.g., Kintsch, 1988) and digital reading (e.g., Leu, Kinzer, Coiro, & Cammack, 2004). We began this project knowing that such influential pieces would not be included in the systematic review due to their theoretical nature. Nonetheless, we considered these works informative in framing our questions, establishing our search parameters, and suggesting relevant researchers and publications. With such formative pieces and our prior empirical studies as guides (Singer & Alexander, 2017; Singer, Alexander, & Berkowitz, 2017), we initiated a systematic search of the literature.

All literature searches were conducted using the ERIC, PsychInfo, and Web of Science databases and a title and abstract search procedure. Furthermore, these database searches were limited to peer-reviewed publications in the English and to the last quarter century (i.e., 1992 to May 2017). We chose this time frame since we were specifically interested in the literature that was not critically examined during Dillon's (1992) review. We also considered this time frame as justified given the rapidly changing nature of digital reading (Underwood et al., 2015). In an effort to address our research questions, we used the terms "reading digitally" ($n = 129$), "reading online" ($n = 111$), "digital reading" ($n = 221$), "computer reading" ($n = 101$), "ereading" ($n = 189$), "learning on computer" ($n = 58$), and "learning digitally" ($n = 57$) to conduct the initial search. This initial phase of the systematic search resulted in 859 documents. Although these various terms were used to search databases, we will consistently refer to *reading* or *reading in print* when describing reading that occurs off-line and to *digital reading* or *reading online* when speaking about reading involving hypermedia technology.

In addition to the aforementioned procedure, we physically examined the table of contents for journals appearing two or more times in the initial search results. For pragmatic reasons, we limited this facet of the search to the past 5 years of journal volumes. The list of those physically searched journals appears in Table 1. We also perused the publication lists for specific authors who contributed two or more studies to our initial database as a way to locate any potential studies that might fit our inclusion parameters (see Table 2). Finally, we used a backward-snowballing method to expand the search. This process entails reviewing the reference lists of

TABLE 1

Journals hand searched for relevant studies

Computers & Education
Contemporary Educational Psychology
Journal of Educational Psychology
Journal of Experimental Education
Journal of Literacy Research
Review of Educational Research
Reading Psychology
Reading Research Quarterly

TABLE 2

Vitas of specific authors searched for relevant publications

Azevedo, R.
Cromley, J. G.
Coiro, J.
Eshet, Y.
Kuriawan, S. H.
Larson, L. C.
Leu, D. J.
Mangen, A.
Noyes, J. M.
Reinking, D.
Roswell, J.
Sutherland-Smith, W.
Zawilinski, L.

identified articles to unearth any previously overlooked documents that appear to fit the search parameters. Collectively, these subsequent search procedures contributed an additional 19 documents to the research pool, bringing the total numbers of works to be further scrutinized to 878 (see Figure 1).

Inclusion Criteria

Beyond the initial search parameters, several specific criteria were established to ascertain which documents in the initial pool should be retained for final analysis. Specifically, studies were included in the final analysis if they fulfilled the following criteria:

1. Involved both print *and* digital reading
2. Were empirical studies
3. Entailed more than self-report measures
4. Included a measure of comprehension as an outcome

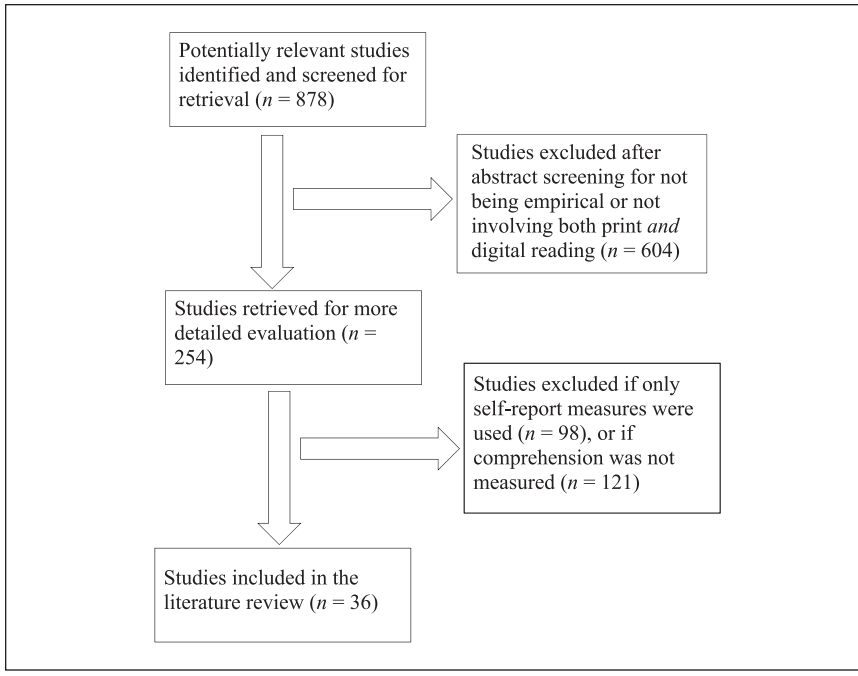

FIGURE 1. *Diagram of article search and screening steps taken to mark studies for exclusion and inclusion in the literature review.*

In effect, publications were retained for analysis only if they featured participants engaged with both print and digital texts. For instance, although it used print reading comprehension scores as a control variable, Coiro's (2011) study on predicting reading comprehension was excluded from this review because the researcher collected data only on digital reading performance. Furthermore, all articles kept for further analysis had to be empirical in nature. This meant that scholarly treatises, anecdotal observations, and reviews (unless meta-analytic) were exempt from inclusion. An example of a review that was excluded for this reason was Tanner's (2014) article, *Digital vs. Print: Reading Comprehension and the Future of the Book.* While interesting as a survey of published works, this article did not entail the reporting of an original empirical study.

The third criterion established for inclusion required that researchers rely on more than self-report data to reach their conclusions. We deemed this step as essential so that there were objective data pertaining to reading in print or digitally. Many of the articles returned by the initial search met the first two criteria but relied only on survey or opinion data. For example, a study by Spencer (2006) examined learners' preferences for reading from a printed text or on a computer screen. However, in this study, she relied solely on participants' self-reported

preferences. She did not document participants' pattern of engagement in any form of print or digital reading activity against which the self-reported preferences could be calibrated.

Finally, to be retained in this review, articles identified through the search process had to include some measure of reading comprehension as an outcome variable. For example, a study by Roth, Tuch, Mekler, Bargas-Avila, and Opwis (2013) examined the effects of object placement on different websites on participants' processing using eye-tracking technology. Although relevant, this study did not meet the final inclusion criterion because the authors did not have any dedicated measure of reading comprehension. In effect, Roth et al. did not attempt to link participants' examination of website objects to their understanding or recall of the textual content displayed on those websites.

Final Pool

Through our database searches, journal hand searches, vita searches of specific authors, and use of backward-snowballing method, the number of potentially relevant documents amounted to 878 unique publications. Figure 1 illustrates this search and screening procedure. Of our initial pool of 878 articles, 604 were excluded when the screening of the abstract demonstrated that those documents either were nonempirical or did not involve both print *and* digital reading. For example, although Topping's (1997) article on reading digitally in school and at home examined a relevant topic, it was excluded from this review because the abstract revealed that this was a document discussing developments in digital reading devices with no original empirical data forthcoming. An example of a study that was excluded after an abstract scan because it did not address *both* print and digital reading was an article by Dalton, Proctor, Uccelli, Mo, and Snow (2011). Although the research was relevant to our review, this article was excluded because the authors only examined comprehension in fifth-grade students reading digitally. Reading in print was not a part of this investigation.

This initial abstract screening phase of review left us with a pool of 254 studies for a full-text screening. Of these 254 publications, 98 studies were excluded for using only self-report measures. For example, a study by Franze, Marriott, and Wybrow (2014) queried 162 academics about their preferences and reading habits in print and digital mediums using an online questionnaire. However, in this study there were no measures that extended beyond self-reported data. In addition, through our full-text screening, we excluded 121 studies that did not expressly measure comprehension as an outcome variable. For example, Eshet-Alkalai and Geri (2007) assessed students' critical thinking skills while reading in print and digitally. However, Eshet-Alkalai and Geri's study did not take into consideration students' comprehension of what they read in any form, thus meriting its exclusion from this review.

These steps in review left us with a total of 36 studies to be charted and analyzed. In effect, these 36 studies served as the database to address our specific research questions. In preparation for analysis, each of the 36 publications was catalogued on the basis of the following: (a) author, (b) year of publication, (c) number of participants; (d) grade level of participants (i.e., elementary, middle

school, high school, college, post-college); (e) participant details (i.e., gender, SES, and special status), (f) text type (i.e., exposition, narrative, or both), (g) text length, (h) text manipulations, (i) setting (i.e., instructional, research, and nonacademic), (j) task, (k) comprehension and other measures administered, and (l) outcomes reported. The full charting of these 36 studies is provided in the appendix (see Supplementary Table S1 in the online version of this journal).

Definitional Coding Scheme

To initiate our analysis of the literature, we coded all included studies based on whether or not definitions of reading or reading digitally were present, and whether those definitions were explicit or implicit in nature. The procedure we followed in this phase of analysis was informed by prior systematic reviews that delved into conceptual patterns with the literature (Baggetta & Alexander, 2016; Dinsmore et al., 2008; Murphy & Alexander, 2000). Specifically, definitions were coded as explicit if the authors' guiding conception of *reading* or *reading digitally* was expressly stated. In contrast, an implicit definition was recorded when the authors' intended definition of *reading* or *reading digitally* had to be inferred from language used through the document.

Furthermore, for those conceptions categorized as explicit, we coded whether the definition was conceptual, componential, operational, or multifaceted. According to the coding scheme established for this purpose, a conceptual definition was viewed as more ontological if it sought to capture the essence of reading or reading digitally. In effect, a conceptual definition would attempt to answer the basic question of *what is* reading or reading digitally by describing its foundational nature. By comparison, a componential definition was one that delineates the elements, skills, or abilities that are regarded as core to reading. Definitions would fall within the category of componential if they sought to answer the question *what does* reading or reading digitally entail. Next, an operational definition was more process-oriented in that it focused on *how* reading or reading digitally was thought to occur. In addition, to be classified as operational, the definition had to do more than simply mention the word *process*. It had to describe that process to some extent. Finally, a multifaceted definition was one that incorporated more than one of the aforementioned categories (e.g., conceptual *and* operational).

To establish the interrater agreement for definitional categories, a four-step coding procedure was employed. Specifically, following initial training using the coding manual, the first author and a trained research assistant working independently first indicated the presence or absence of any explicit or implicit definition for reading or digital reading in all 36 documents. There was complete agreement on this initial decision, so the remaining steps of the coding procedure were initiated. In Step 2, working independently, documents that included some form of a definition were coded for whether the authors' delineation was explicitly stated or required inferencing on the coder's part. For explicit definitions, coders recorded the authors' exact language, while for implicit definitions the words or phrases in text that were the basis for the inferred conception were recorded. Next, in Step 3, the coders made a determination as to

whether explicit definitions were conceptual, componential, operational, or multifaceted in nature. To assist in this more fine-tuned analysis, the coding manual included the *what is*, *what does*, and *how* descriptions for conceptual, componential, and operational definitions, respectively. When more than one of these descriptions was present, the definition was coded as multifaceted. The level of interrater agreement for Steps 2, 3, and 4 collectively was 97.14%.

Text Length Categories

When charted articles included word counts of the texts read (36.11% of the 36), the texts were classified as either short or long in length. This decision to categorize article according to text length was based on reported associations between length and medium for texts longer than one page (Wästlund, 2007; Wästlund, Reinikka, Norlander, & Archer, 2005). Specifically, Wästlund and colleagues contended that the need to scroll with longer online texts increased the cognitive demands on readers and, thus, appeared to negatively affect recall for digital medium. Using a printed page as the guideline, we calculated that the word count for a page of published text roughly equated to 500 words. Thus, texts were coded as *short* if they were under 500 words in total and *long* when the word count was 500 words or more. This decision rule was applied in an attempt to disambiguate the potential role of text length in terms of comprehension outcomes reported.

Research Setting Categories

Included studies were coded as following for the setting in which the research took place: I = instructional, R = research, and NA = nonacademic. Instructional settings referred to studies where data were collected within the participants' academic setting (e.g., classroom, computer lab, after-school program). Settings were coded as *research* when data collection occurred within a more controlled or contrived context, such as a laboratory. Finally, settings were coded as nonacademic when the study took place outside of a school or educational context, such as a home-based study. This decision rule was applied in an attempt to examine the potential role setting might play on the reported outcomes.

Results and Discussion

Research Question 1: Defining Reading and Digital Reading

The first goal of this systematic review was to examine how those engaged in research on reading in print *and* digital forms conceptualized *reading* and *digital reading*. In terms of conceptualization, we sought to explore not only the explicit definitions incorporated in the articles but also any definitions that we could extrapolate from the words and phrases employed by the researchers in the discourse. Although we had no particular expectations regarding the frequency or nature of the definitions that might populate this body of work, we were unpleasantly surprised by the paucity of either explicit or implicit definitions we could document for either reading or digital reading.

Conceptualizing Reading

Specifically, of the 36 charted studies (see Supplementary Table S1 in the online version of this journal), only 9 (25%) included any manner of definition of

reading—be it explicit or implicit. Given the relatively small number of studies with explicit or implicit definitions of reading, we consolidated the definitions for reading and for digital reading in Table 3. Of those nine articles, eight (22.22%) contained explicit definitions, where the guiding conception of reading was expressly indicated. In three of those instances, the provided definitions were conceptual in nature. For example, Stern and Shalev's (2013, p. 1) definition (i.e., "Reading is a complex process [that] involves multiple components and is affected by various factors") is a conceptual definition because it speaks broadly about the nature of the process but does not explicate on the components and processes occurring.

There was one article whose authors (Ali, Wahid, Samsudin, & Idris, 2013) explicitly defined reading componentially by delineating the elements, skills, or abilities regarded as core to reading. Specifically, these authors stated that reading required "understanding words, sentences, and paragraphs" (p. 27). Only one article contained an operational definition of reading. This article by Ortlieb, Sargent, and Moreland (2014, p. 4) cited the process-oriented definition for reading forwarded by Anderson and Pearson (1984, p. 55) who described reading as involving "the retrieval of previously acquired schema to assist the processing and understanding of new unfamiliar information." The final two explicit definitions were multifaceted in nature. For example, Singer and Alexander (2017, p. 4) defined reading as "an active, constructive, meaning-making process . . . readers are expected to form connections between their own prior knowledge and the ideas expressed in or inferred by the text per se." This definition was coded as including both conceptual ("what is") and operational ("how") elements.

Finally, only one definition could be assembled from words and phrases the authors used within the document. This implicit definition came from the article by Mayes, Sims, and Koonce (2001). Our assemblage of the implicit definition, which follows, is indicated by (a) presenting the authors' exact words in italics, (b) employing brackets to show text segments appearing in different locations in the text, and (c) using regular text to indicate the connecting words or phrases added to make the definition more coherent.

> Reading *[relies on working memory] [to retain words to allow the reader to link words together in a meaningful process].* Reading also includes [*word recognition]* and other [*processes that occur automatically].*

Conceptualizing Digital Reading

Unfortunately, the definitions of digital reading were similarly scant to those for reading. Only five articles (13.89%) included a definition of digital reading in any form. Within this small subset, two definitions were explicit and the remaining three were implicit. For example, the explicit multifaceted definition forwarded by Margolin, Driscoll, Toland, and Kegler (2013, p. 7) summarized the five components for reading online offered by Leu et al. (2004): "identifying a problem, locating information, evaluating the information, synthesizing information, and communicating information." The authors then expounded on those components by stating,

TABLE 3

Definitions provided in included studies

Source of information		Definition	
Authors	Year	Reading	Digital reading
Ali, Wahid, Samsudin, and Idris	2013	ECP, Understanding words, sentences, and paragraphs (p. 27)	
Eden and Eshet-Alkalai	2013	EM, Active reading (i.e., the reader's ability to edit a given text and demonstrate comprehension by identifying and correcting text errors (p. 3)	
Lenhard, Schroeders, and Lenhard	2017	EM, In advanced text comprehension, however, vocabulary, background knowledge, reading strategies, and reasoning abilities play a more prominent role . . . and the importance of reading fluency gradually declines (p. 2)	
Margolin, Driscoll, Toland, and Kegler	2013	ECO, Reading is a process that, once learned, allows an individual to mentally represent written text (p. 1)	EM, Leu et al. (2004) describe five components for online reading: identifying a problem, locating information, evaluating the information, synthesizing information, and communicating information. The description of these components suggests that reading online involves more than simply understanding what is encountered. It also suggests that the reader engage in other higher level processing of the material beyond creating a mental representation of the text (p. 7)
Mayes, Sims, and Koonce	2001	IM, Relies on working memory to retain words to allow the reader to link words together in a meaningful process. Also includes word recognition and other processes that occur automatically	IM, Two processes occurring; visual system must be able to perform under new demands and cognitive effort is different

(continued)

TABLE 3 (CONTINUED)

Source of information		Definition	
Authors	Year	Reading	Digital reading
Ortlieb, Sargent, and Moreland	2014	EO, Reading comprehension results from the retrieval of previously acquired schema to assist the processing and under- standing of new unfamiliar information (Anderson & Pearson, 1984) (p. 4)	IM, Ability to engage in textual reading and interactions
Siegenthaler, Wurtz, Bergamin, and Groner	2011		IM, That e-ink technology allows for a reading process that is similar to that of reading print (p. 2)
Singer and Alexander	2017	EM, An active, constructive, meaning-making process . . . readers are expected to form connections between their own prior knowledge and the ideas expressed in or inferred by the text per se (p. 4)	
Stern and Shalev	2013		EM, Consuming information based on cognition. Information is encoded, organized, stored, remembered, and applied (p.11)
Wästlund, Reinikka, Norlander, and Archer	2005	ECO, Reading is a complex process which involves multiple components and is affected by various factors (p.1)	
Young	2014	ECO, comprehension requires many different sub-processes, which include knowledge integration, coherence, and parsing (p. 6)	

Note. ECO = conceptual explicit; ECP = componential explicit; EO = operational explicit; EM = multifaceted explicit; IM = implicit.

> The description of these components suggests that reading online involves more than simply understanding what is encountered. It also suggests that the reader engage in other higher level processing of the material beyond creating a mental representation of the text. (p. 7)

This was considered an explicit multifaceted definition because it addressed both conceptual and componential elements of reading digitally.

It is conceivable that the lack of dedicated definitions of digital reading reflects the researchers' unstated perception that the distinction between reading and reading digitally has more to do with the context of the process and is not some reconceptualization of the basic construct. We see evidence of that perception in the implicit definition of digital reading we were able to assemble from Siegenthaler, Wurtz, Bergamin, and Groner's (2011) article:

> Reading digitally requires *[e-ink technology]* that *[allows for a reading process that is similar to that of reading print]*.

Research Question 2: The Assessment of Comprehension

The second question that guided this analysis focused on the assessment of comprehension within the literature on reading in print and digitally. For this analysis, we initially set out to examine the form of those assessments (e.g., multiple-choice, free-recall, or constructed-response). Then, we wanted to explore the level of understanding these assessments tapped (i.e., locate and recall, integrate and interpret, or critique and evaluate; NAGB, 2008). We determined that there was noticeable variability in the measures and approaches that researchers employed to test participants' comprehension. For example, 15 studies included multiple-choice reading comprehension questions (e.g., 10 multiple-choice reading comprehension questions; Noyes, Garland, & Robbins, 2004). Six studies included short-construction questions (e.g., three short-response items; Singer & Alexander, 2017). The remaining studies incorporated comprehension questions that were unspecified, free recalls, or text summaries.

We also noted that a majority of researchers employed multiple comprehension measures (61.11%). For example, Kerr and Symons (2006) used free recall, eight cued-recall multiple-choice questions, and seven cued reading comprehension multiple-choice questions to assess comprehension. Although this effort to include multiple indicators of reading comprehension is a positive characterization of the charted literature, other documented patterns raised critical questions. For instance, the psychometric properties of study measures were not always well documented. Moreover, the majority of the studies (63.89%) involved researcher-developed measures of reading comprehension rather than established assessments, and in many of those instances (91.42%), the reliability and validity of data from those research-developed measures were not provided. For example, Noyes et al. (2004) detailed their comprehension task as consisting of "10 multiple-choice questions following by the administration of the NASA-TLX" (p. 112). Although their measure of comprehension may be a sound choice, the lack of details regarding reliability and validity is concerning.

Research Question 3: Analyzing the Trends

The third issue about which we queried the literature pertained to what trends, if any, could be discerned from the past quarter century. Building on prior work (Alexander et al., 1996; Alexander et al., 2012; Alexander & Knight, 1993; Dumas et al., 2015), we sought to ascertain whether trends shaping reading comprehension in print and digitally could be identified. Given the relatively short time span for this trend analysis, we recognized that the ability to discern patterns would prove challenging. For that reason, we initially broke the span of this analysis (i.e., 25 years) into three 8-year time periods (i.e., 1992–2000, 2001–2008, and 2009–2017). However, because we identified no published studies meeting our criteria for 1992 to 2000, we excluded that time period from further trend analysis. We then explored whether the components we charted (e.g., participants' academic level, number of text sources) manifested dramatic (incremental), little (stationary), and variable (iterative) changes. Thus, Table 4 displays the summary of the components over the two time periods where publications occurred (2001–2008 and 2009–2017).

Incremental Trends

We first examined the summarized data to identify if any of the charted components displayed dramatic upward shifts (Alexander et al., 1996, Alexander et al., 2012; Alexander & Knight, 1993; Dumas et al., 2015). It is important to note that the identification of a trend as *incremental* was not predicated on any specific numerical criterion. Rather, this designation indicated a clearly discernible increase over time with no evidence of decrement. Based on that description, we identified four components from this exploration that fit that this dramatic, upward shift: number of studies conducted, data sources included and amount of data gathered, the variety of digital devices employed, and the number of texts processed.

Number of studies conducted. When we initiated this systemic review, it was our expectation that we would find a number of empirical studies at each of the three time intervals designated. Perhaps the most surprising finding from this review was the determination that there were no studies involving the reading of texts under both print and digital conditions between 1992 and 2000 that met our selection criteria. In contrast, there were 14 documented studies between 2001 and 2008 and 22 investigations published between 2009 and 2017. We regard this movement from 0 to 14 to 22 as indicative of an incremental trend.

In trying to understand this development, we can make several observations. For one, research on digital reading remained active during the 1992 to 2000 time period (Chu, 1995; Hartas & Moseley, 1993; Soe, Koki, & Chang, 2000). The nature of that research, however, made it inappropriate for inclusion in this review. In effect, it appeared that the need to juxtapose processing in print to digital processing proved a less pressing concern. Rather, efforts during this period seemed to be allocated to demonstrating that "online reading" or "digital reading" was a unique cognitive activity that warranted focused empirical energy (Kellner, 2000; Lankshear & Bigum, 1999; Leu, Leu, & Leu, 1999). Furthermore, the resurgence

TABLE 4

Summary of study components by publication period

Study component level	2001–2008, *n* (%)	2009–2017,[a] *n* (%)
Charted studies	14 (38.89)	22 (61.11)
Data sources		
One	8 (57.14)	4 (18.18)
Two	2 (14.29)	13 (59.09)
Three or More	4 (28.57)	5 (22.73)
Digital devices used		
One	13 (92.86)	20 (90.90)
Two	1 (7.14)	2 (9.10)
Participant academic level		
Early elementary	2 (14.29)	3 (13.63)
Middle school	1 (7.14)	2 (9.11)
High school	0 (0.00)	3 (13.63)
College	10 (71.43)	11 (50.00)
Postcollege	1 (7.14)	3 (13.63)
Text sources		
One	10 (71.43)	12 (54.55)
Multiple	4 (28.57)	10 (45.45)
Digital devices		
Computer	11 (78.57)	13 (59.09)
Other	3 (21.43)	9 (40.91)
Text genre		
Narrative	2 (14.29)	5 (22.73)
Expository	12 (85.71)	11 (50.00)
Both	0 (0.00)	6 (27.27)
Text length		
Shorter	4 (28.57)	4 (18.18)
Longer	3 (21.43)	4 (18.18)
Not provided	7 (50.00)	14 (63.64)
Manipulated texts		
Manipulated	4 (28.57)	8 (36.36)
Not manipulated	10 (71.43)	14 (63.64)
Setting		
Research	7 (50.00)	12 (54.54)
Instructional	6 (42.86)	8 (36.36)
Nonacademic	1 (7.14)	2 (9.11)

[a]All studies were charted that were available at date of submission, May 1, 2017.

of interest that occurred in the subsequent period (2001–2008) coincided with peak sales in personal computer (Reimer, 2005) and emerging debates over the

nature of reading in print and digital forms (Kerr & Symons, 2006; Kurniawan & Zaphiris, 2001; Macedo-Rouet, Rouet, Epstein, & Fayard, 2003), which may have served as catalysts.

In the period between 2009 and 2017, the increased availability of personal computers was followed with a sharp rise in the availability and affordability of handheld devices, including smartphones and tablets (Zickuhr & Rainie, 2014). A good number of these new devices were developed primarily for use as eBooks or eReaders. Perhaps the growing presence of hypermedia both in and out of schools and the growing popularity of digital reading devices spurred questions about the effect of such medium on students' reading and learning from text.

Increased data sources. During the past quarter century, researchers also gathered increasingly more data about readers engaged in the processing of print and digital texts. As shown in Table 4, the majority of studies published between 2001 and 2008 (57.14%) reported only one indicator, which by default was a measure of reading comprehension. In contrast, the majority of studies appearing between 2009 and 2017 included two (59.09%) or more (22.73%) data sources. This noticeable shift in the number of data sources may be partially attributable to the ease at which information can be collected not only prior to or after reading but also during the processing of print and especially digital texts.

Support for the aforementioned contention can be found in the forms of data collected. Specifically, for the period of 2001 to 2008, only one investigation (7.14%) included any physiological data (e.g., eye movement or heart rate). In that investigation, Wästlund et al. (2005) recorded heart rates of participants while they engaged with the reading task. This compares to five (22.73%) studies published between 2009 and 2017 that incorporated some form of physiological data source. In one such study, Siegenthaler et al. (2011) recorded eye movements using an infrared video eye-tracking device as college students read texts.

Variety of digital devices. There was also a sharp increase in the availability and affordability of digital devices across to time periods, including those dedicated to digital reading, such as eBooks or eReaders (Tyner, 2014). Not surprisingly, therefore, the use of noncomputer devices exhibited a noticeable increase from 2001–2008 (n = 3, 21.43%) to 2009–2017 (n = 9, 40.91%). For example, De Jong and Bus (2004) used an animated eBook to examine reading comprehension, while Zambarbieri and Carniglia (2012) used a laptop and eReader as separate conditions within their study. The focus on handheld and portable devices in recent investigations of print and digital reading is understandable given the broad popularity of eReaders. In fact, Zickuhr et al. (2012) reported that those reading digitally read on average twice as many books as those reading print books.

Moreover, the actual design of the digital reading devices has proven intriguing to researchers, such as the effects of print size, scrolling features, or ergonomic features on cognitive functioning (Stoop, Kreutzer, & Kircz, 2013). Thus, the field has witnessed not only increased use of noncomputer devices in the charted studies but also more empirical attention to the effects of differing digital devices on text processing and reader comprehension (Kim & Anderson, 2008;

Margolin et al., 2013). This may help explain the appearance of nine (40.91%) studies during the period of 2009 to 2017 that incorporated a digital device other than a desktop computer. For example, Zambarbieri and Carniglia (2012) analyzed comprehension and eye movements of participants when reading from a printed book, computer display, and a handheld eReader. What these researchers largely determined was that there were no significant differences in comprehension across devices.

Number of texts processed. Perhaps the clearest example of a dramatic shift can be seen in the number of texts that participants were required to process in print and digitally. Were we to pose the question, "Did charted studies involve one or more than one text," the answer would seem rather definitive. Specifically, the majority of charted studies (69.44%) entailed the reading a single text under print and digital conditions. For two of those studies, researchers actually used multiple segments from the same text to assess print and digital reading (Siegenthaler et al., 2011; Zambarbieri & Carniglia, 2012).

However, this overall percentage is misleading when identified studies are examined by two time frames—before 2003 and after. To be more precise, prior to 2003, we identified no instances of multiple text sources being employed in the research on print and digital reading. After 2003, 36.11% (13) of the charted studies used multiple texts to investigate print and digital reading. This sharp rise in the use of multiple texts coincides with the emergence of theoretical and empirical models of multiple source use that have begun to populate the literature. Those models include the Multiple Documents-Task-Based Relevance Assessment and Content Extraction (Rouet & Britt, 2011), the content-source integration model (Stadtler & Bromme, 2007), and the discrepancy-induced source comprehension model (Braasch, Rouet, Vibert, & Britt, 2012). Given the burgeoning interest in multiple-text comprehension, and the new models that are populating the literature (e.g., cognitive affective engagement model; List & Alexander, 2017), we expect this upward trend to continue into the years to come.

Stationary Trends

Based on our analysis of the literature, we identified four components of the empirical research on print and digital reading that have remained rather consistent over the past 25 years: participants' academic level, text genres, research settings, and task specifications.

Participants' academic level. While interrogating the literature, we concluded that the majority of studies (88.89%) involved school-age readers (i.e., early elementary through college), and this pattern held whether the time frame was 2001–2008 or 2009–2017. In fact, of the 36 charted studies, only four included postcollege or adult readers (e.g., DeZee, Durning, & Denton, 2005). Furthermore, when we considered the breakdown of school-age populations, we found that only four studies had early elementary readers as the focus (e.g., Kim & Anderson, 2008), and even fewer ($n = 3$) centered on middle school readers (e.g., Puhan, Boughton, & Kim, 2005).

By far the population of greatest interest in analyzed studies was college students (e.g., Annand, 2008; Foasberg, 2014). This was true whether the studies were published between 2001 and 2008 (71.43%) or 2009 and 2017 (50%). Why readers at this academic level were selected, however, was left to speculation, since it was rare for researchers to offer any rationale for their choice of undergraduate readers. In fact, Singer and Alexander (2017) were the only researchers targeting undergraduates who provided a theoretical or empirical justification for this design decision. This pattern begs the questions of whether college readers represent a sample of convenience.

Text genre. Another rather consistent pattern over the course of this systematic review related to the text genres and also the genres read by participants within age/grade groups. For instance, when we look across the two periods in terms of genres, we observed that exposition remained the favored form of text used in the empirical studies (85.71% and 50%, respectively). However, the nature of the trend for genre became even clearer when we examined the relation between genre and participants' academic level. Specifically, when the participants were early elementary students, researchers relied solely on narrative texts (e.g., De Jong & Bus, 2004; Jones, 2011; Kim & Anderson, 2008; Ortlieb, Sargent, & Moreland, 2014). In contrast, 79.41% of the studies involving college readers employed only expository text or exposition and narrative combined. Granted, it may be understandable that narrative texts were more evident within these earlier grades. However, the absence of any exposition for these younger readers is questionable, especially when attempting to understand how reading comprehension transpires in print or digital mediums. For instance, the Reading Framework for the 2009 NAEP (NAGB, 2008) has suggested that exposition should account for 50% of texts read in Grade 4. Furthermore, prominent reading researchers have decried the lack of exposition within the early elementary grades (Dreher, 2003; Duke, 2000; Duke & Pearson, 2008).

Research setting. Another rather consistent pattern over the course of this systematic review concerned the setting in which the research was conducted. As mentioned, studies were coded into one of the three following setting categories: instructional, research, or nonacademic. When we looked at the publications for the two time periods, we found that the majority of studies took place in a research setting (50% and 54.54%, respectively). For example, Siegenthaler et al., (2011) monitored participants' eye movements while they read novels and answered comprehension questions. Given the sophisticated equipment required to monitor eye movement, it is no surprise that this study, like the majority of the others in our review, was conducted in a laboratory context.

Also, the number of studies conducted in classrooms or other academic context, like the school computer lab, held rather steady across the two time periods (42.86 and 36.36, respectively). Many of these researchers spoke to their desire to collect data in a setting where reading in both mediums was familiar and natural to their participants. For instance, Ortlieb et al. (2014) chose to conduct research in an after-school reading intervention program to more naturalistically investigate the role of medium in comprehension. Finally, there were very few studies in

either time period that collected data in a nonacademic setting, such as the readers' home (n = 3). Two of those studies involved young children reading with parents in the home (e.g., De Jong & Bus, 2004), a common literacy activity at this age (Baker, Dreher, & Guthrie, 2000).

Task specifications. When it came to examining the study tasks, we found it difficult to discern the precise nature of the directives given to participants. This is surprising given that research suggests that task demands influence both the processes and the products of text engagement (McCrudden, 2011; McCrudden, Magliano, & Schraw, 2010). Nonetheless, even if not explicitly stated within the text, we were able to discern a certain pattern that showed little variance over time. Specifically, for the majority of studies in both time periods, participants were directed to read in order to answer questions about what they read (85.71% and 81.82%, respectively). Given this lack of task-specific information for most of the analyzed studies, we were hampered in the determination of whether the characteristics of task had a significant role to play in reading in print or digitally.

Iterative Trends

Iterative trends, according to Alexander and Knight (1993), are those movements or events that continually reappear on the educational landscape. Due to the rather restrictive time frame of this review, iterative trends may be more clearly described as charted components displaying fluctuations. With that qualification in mind, we identified two components that we regarded as interactive in character: degree of text manipulation and text length.

Text manipulation. If one were to look solely at the number of studies involving text manipulations in some form, it would appear that this charted component would fit the description of a stationary trend. However, a deeper examination revealed a substantial degree of fluctuation across the two time periods. To be more specific, in investigations of print and digital reading, a majority of researchers during the two time periods elected to present texts in an unaltered manner (71.43% and 63.64%, respectively). For example, Zambarbieri and Carniglia (2012) compared text processing while reading across a desktop PC, iPad, eReader, and a print book but retained the character of the texts. In another study, while counterbalancing the order in which the texts and mediums were presented, two Microsoft Word documents that had been read by some in print were simply uploaded onto a computer when participants were ask to read digitally (Ackerman & Lauterman; 2012).

However, what are not conveyed in these overall percentages are the degree and form of manipulation that occurred in a substantial number of studies dispersed across the two time frames (n = 11, 30.56%). Those manipulations included changing the fonts in size and character, varying the line spacing, and altering the number of columns on each page. For example, Stern and Shalev (2013) presented high school students with passages of equal difficulty in print and digital form that had different spacing features (single-spaced text or double-spaced text). These researchers wanted to determine if manipulating the spacing of text

affected participants' reading comprehension abilities. What Stern and Shalev reported was that there was no main effect for text spacing on comprehension. However, there was a significant interaction between medium, spacing, and attention level of the reader. Specifically, when the high schoolers had good attention as measured by eye-tracking, they performed best when the text was digital and single-spaced. Conversely, when attention was medium or poor, participants performed worse on the digital, single-spaced text.

Scrolling was another text feature that researchers intentionally manipulated. In one study, Singer and Alexander (2017) reduced the length of selected passages so the target text would fit on one page of text. Their reason for this manipulation was to eliminate the need for scrolling in order to control for the increased cognitive load brought up by navigational issues when scrolling (Wästlund, 2007). Other researchers have investigated the effects of scrolling on readers' performance in digital environments. For example, Kerr and Symons (2006) manipulated the digital text precisely to require scrolling for some readers. On the basis of this manipulation, these researchers concluded that the demands associated with scrolling contributed to a greater efficiency in processing in print versus digitally.

Alternatively, Kurniawan and Zaphiris (2001) tested the effects of one-, two-, and three-column formats on middle-aged and senior readers' preferences for and understanding of texts. What they determined from this manipulation was that the number of columns did not matter for these mature readers. Interestingly, these older readers were found to read more quickly in print than digitally, a finding that was an anomaly with regard to the relation between speed and medium within this review.

Of all the studies that incorporated text manipulation, the one by De Jong and Bus (2004) was clearly an outlier due to the degree of manipulation. These researchers were investigating children's emergent story understanding across print and digital stories. Toward that end, they created digital versions of a fiction story for younger readers that included animations placed throughout the text. De Jong and Bus also added interactive features, such as the option to have an animated character start or stop reading the words to the participant. What these researchers found was that the inclusion of text animations and other augmentations did not did not increase these emerging readers' comprehension, as they had predicted. In fact, it was noted that these emergent readers did better on all indicators (i.e., words, phrase, and story structure) under the print versus electronic condition. The researchers attributed to the children's greater familiarity with printed rather than electronic texts. Given that this investigation was conducted more than a decade ago and in light of the markedly increased presence of digital materials in the lives of young children, it would be interesting to empirically determine if the same outcomes would result today.

Text length. Our initial intention in charting text length was to examine if this factor was associated with comprehension outcomes when participants read in print and digitally. Based on prior studies, there was the expectation that longer texts that would require scrolling would increase the demands on reading digitally. For

that analysis, we classified text as shorter (i.e., ≤500 words or ≤1 page) or longer (i.e., ≥500 words or ≥1 page) in length. However, in terms of trends, we determined that a clear majority of studies for both the 2001–2008 and 2009–2017 periods provided no information about the specific length of texts used (50% and 68.18%, respectively). Yet, among those studies where length was specified (41.67%), we observed that there was a high level of variability in the length of texts used across the time periods. For instance, as shown in Table 4, there were comparable numbers of studies for the two time periods that used shorter and longer texts. However, those texts ranged in length from a single sentence (Lenhard, Schroeders, & Lenhard, 2017) to 2,500-word documents (Stakhnevich, 2002).

Even more intriguing was the outcome we identified when text length was juxtaposed to the outcomes reported for print or digital mediums. Specifically, when we took into account the length of texts processed in print or digitally, the otherwise fuzzy picture for the relation between medium and comprehension outcomes came into clearer focus. More precisely, there were conflicting findings reported across all charted investigation as to when the medium of delivery related in any meaningful way to participants' comprehension. Some studies reported that reading comprehension was better in print than in digital (e.g., Mangen, Walgermo, & Bronnick, 2013; Noyes et al., 2004), while others documented better comprehension when readers processed texts digitally rather than in print (e.g., Kerr & Symons, 2006; Verdi, Crooks, & White, 2014). Still other researchers found no significant differences in reading comprehension for print or digital mediums (e.g., Akbar, Al-Hashemi, Taqi, & Sadeq, 2013; H. K. Lee, 2004; Rockinson-Szapkiw, Courduff, Carter, & Bennett, 2013; Young, 2014).

However, on closer examination, we were able to discern an association between text length and medium. Specifically, when the texts being processed were shorter in length, there was no significant effect for medium on comprehension (e.g., Ali et al., 2013; Dundar & Akcayiri, 2012; Eden & Eshet-Alkalai, 2013; Margolin et al., 2013) or comprehension was significantly better in the digital versus print medium (e.g., Kerr & Symons, 2006). However, when the text involved more than 500 words or took up more than a page of the book or screen, comprehension scores were significantly better for print than for digital reading (e.g., Davis & Neitzel, 2012; Mangen et al., 2013; Mayes et al., 2001). This interaction between text length and medium, which we regard as an important finding, was evidenced for 91.67% of the charted studies in which researchers specified the text lengths being processed.

The sole exception to this length by medium pattern was the study by Stakhnevich (2002) in which English as a Second Language (ESL) learners read about Mississippi culture and history and then completed a 20-item multiple-choice comprehension measure. What Stakhnevich found was that participants, who were students that had arrived in the United States within the past 2 weeks and whose primary language was not English, performed better on a comprehension measure after reading 2,500-word texts digitally. However, there are several features of this specific investigation that might have led to its deviation from the observed length by medium pattern. For one, the study involved a special population (i.e., ESL learners) and the processing of texts on unfamiliar topic (i.e., Mississippi culture and history). The digital version of the texts included an online

glossary and dictionary access, which surely would be helpful for newly enrolled ESL students. Furthermore, the small sample size ($n = 31$) and lack of data sources beyond the comprehension measure are certainly limitations to weigh when considering this outlier.

Despite the aforementioned exception, the pattern that emerged for medium by text length could perhaps be explained by processing differences when texts are presented in segments versus continuously. In effect, shorter texts, whether on paper or on screen, could be taken in via routine saccadic eye movements and fixations (Siegenthaler et al., 2011). By contrast, longer texts conveyed digitally required readers to scroll between portions of the text, and the empirical evidence suggests that frequent scrolling within a digital environment increases the cognitive demands on readers (Proaps & Bliss, 2014; Wästlund, 2007). Such increased cognitive demands could, therefore, translate into diminished comprehension or poorer recall for even older participants processing digital texts (Wästlund, 2007).

Research Question 4: Similarities and Differences in Trends Across Time

Our fourth research question called for a comparison of the incremental, stationary, and iterative trends just described with those previously reported. To make this comparison, we turn back to the findings that Dillon reported in his 1992 review, which was the takeoff point for this current investigation. Although the number of trends unearthed in this review were more numerous than those that Dillon forwarded, we identified two points of comparison that merit discussion: the design and conduct of the reviews, and evidence-based conclusions.

Design and Conduct of Reviews

There were two shared attributes between Dillon's (1992) review and the current analysis of the literature. Fundamentally, both reviews were undertaken for the purpose of understanding the relative benefits and consequences of reading in print or digitally by analyzing the work of others. Toward that end, Dillon and we elected to consider only those published works in which participants processed text under both print and digital conditions—a commonality in reviews that was an artifact of search parameters and selection criteria. Another artifactual difference between the two reviews pertained to temporal scope. Although Dillon never explicitly stated the time frame for his review, we deduced from the works he referenced that his analysis spanned 34 years, with the earliest piece appearing in 1958 and the oldest in 1992. Our current review, in contrast, encompassed 25 years (1992–2017). Beyond this common ground, however, there were several features of the design and conduct of these reviews that set these two reviews apart.

For one, as mentioned, Dillon's (1992) review was not systematic in its design. In effect, it was not evident how the relevant literature was sampled in that review or what other criteria beyond the identification of studies involving both print and digital reading were established to determine the inclusion or exclusion of works. Furthermore, there was no systematic charting of identified studies referenced or provided. This fact complicated the ability to judge the validity or strength of Dillon's conclusions. Our review differs in that we systematically searched and charted the literature (see Supplementary Table S1 in the online version of this journal) and based our findings on documented outcomes.

In addition, while the emphasis of the 1992 review was on empirical studies, Dillon referenced other forms of publications in substantiating his findings, such as Tinker's (1958) literature review. In contrast, our inclusion criteria required articles to be empirical publications. Furthermore, while not explicitly stated, the articles included in Dillon's review did not necessarily include any explicit measure of reading comprehension or performance. Instead, studies that collected only self-reported preference data were also analyzed (e.g., Cakir, Hart, & Stewart, 1980). By comparison, our inclusion criteria required that researchers measured participants' comprehension in some manner and that the study rely on more than self-report data. Our overarching goal was to construct a foundation for understanding the potential influence of medium (i.e., print or digital) on what readers understood or recalled. We also wanted to base our interpretations on something other than readers' self-perceptions, which are often inaccurate (Ackerman & Goldsmith, 2011; Hacker, Bol, & Bahbahani, 2008; Singer & Alexander, 2017).

Evidence-Based Conclusions

As stated, questions can also be raised about the strength of Dillon's (1992) conclusions and the substantiation of resulting claims. Dillon, in effect, made certain claims about reading in print or digitally but tended to support such claims with descriptions of particular investigations rather than with data drawn from the collection of studies. For example, Dillon's review concluded, "Without evidence to the contrary though, it would seem as if reading from VDUs [visual display units] does not negatively affect comprehension rates" (p. 9). As support for this contention, Dillon stated,

> The most recently published study covering this issue is by Muter and Maurutto (1991) who asked readers to answer questions about a short story read either on paper or screen immediately after finishing the reading task. They reported no significant comprehension difference between readers using either medium. (p. 9)

Whether the Muter and Maurutto (1991) study was typical or an anomaly was left to the imagination. As a counter to Dillon's (1992) approach, we sought to discuss outcomes that represented trends across a body of empirical work and that could, thus, be quantitatively supported.

Furthermore, Dillon's (1992) approach was to present findings factor by factor (e.g., reading rate or eye movement) in his review. For example, there was an entire section of the review summarizing four articles that had incorporated eye movement data. As a consequence of this approach, Dillon did not attempt to consolidate such individual findings in any significant way. Nor did Dillon look expressly at the potential interaction among variables, such as the role that text length might play in reading performance in print or digital condition. Moreover, Dillon's approach to examining isolated factors such as reading rate, while overlooking the interplay with other factors like text length, may have masked important conclusions to be reached. We see this approach as contributing, in part, to Dillon's tendency to report more inconclusive findings, which he attributed to "the variety of methodologies, procedures and stimulus materials employed in these studies" (p. 11).

Conclusions and Implications

It is important to state that we did not undertake this review to judge if reading digitally belongs in our society. The ubiquity of reading digitally has already answered that question. In fact, as time and technology progress, the convenience of reading digitally fortifies its stake. Indeed, the ubiquity of technology is one of the reasons a systematic review of reading in print and digitally seems warranted. To our knowledge, this is the only systematic review on the topic of reading in different mediums since 1992 that juxtaposes the contemporary field of reading digitally against the long-established and deep-rooted research on reading in print.

Our goal of understanding print vis-à-vis digital reading increases in urgency as high-stakes assessments move to digital formats. For example, undergraduate and graduate entrance assessments such as the Scholastic Aptitude Test (College Board, 2009) and the Graduate Record Examination (Educational Testing Service, 2013) are primarily administered digitally. Furthermore, national and international assessments, such as the Programme for International Student Assessment (PISA, 2015) and NAEP (NAGB, 2008), are instituting digital administration, as well as scenario-based tasks that incorporate digital literacy. Consequently, we have a responsibility to try to understand what consequences may arise for readers when high-stakes reading assessments are not only delivered digitally but also include features such as animations or video.

Furthermore, researchers have a responsibility to define what they mean by reading and to indicate whether that general definition suffices regardless of medium (i.e., print or digitally) or of the digital features that are introduced into text. Our systematic review determined that the majority of studies failed to define either reading or digital reading. Moreover, those relatively few researchers who did explicitly or implicitly define reading did not seem compelled to similarly define digital reading explicitly or implicitly (e.g., Kerr & Symons, 2006; Kurniawan & Zaphiris, 2001; Lenhard et al., 2017). In those instances, we might assume that these researchers perceived no difference for the processing of text across print and digital mediums—a perception that has been questioned by others (e.g., Coiro, 2011; Leu, Kinzer, Coiro, Castek, & Henry, 2013).

Conversely, for those even rarer researchers who expressively defined reading *and* reading digitally (Margolin et al., 2013; Mayes et al., 2001; Ortlieb, Sargent, & Moreland, 2014), the focus was often on the unique processing demands that come with processing in an online environment. In effect, for these researchers, there appeared to be an intention to distinguish between *reading digitally*, where traditional texts are simply delivered via hypermedia with few enhancements (Bodmann & Robinson, 2004), and *digital reading* (Singer et al., 2017), where the ability to function within the Internet world instigates new cognitive processes or processing skills for navigating the many elements and features on websites, including text. The high-stakes assessment of reading is not immune to the conundrum of distinguishing between reading digitally and digital reading. In fact, the Programme for International Student Assessment 2015 Reading Literacy Framework specifies that their digital assessment of reading relies "on a set of fundamental skills for using computers" (Organisation for Economic Co-operation and Development, 2015, p. 29).

Beyond this more conceptual quandary, there was other news, more or less positive, to report. On one hand, the reviewed studies provided more information about what was read than how reading was defined. Of the 36 included studies, 33 provided some details about aspects of the text, such as text type and length. On the other hand, the details provided were often insufficient. Specifically, of the 33 studies that provided any information about the text, only 8 provided details regarding *both* text type and length. This lack of specificity concerning aspects of the text is particularly problematic because research has established that aspects of the text, such as text type and length, play an important role in reading comprehension (Graesser, McNamara, & Louwerse, 2003; Kendeou, Muis, & Fulton, 2011; Kintsch, 1980). Certainly, in this review, we were able to understand the potential comprehension decrement that comes from reading longer texts digitally rather than in print. There may be even more to uncover about textual aspects and their effect on reading comprehension for print and digital mediums, but those understandings will remained buried without sufficient probing.

In addition to the aforementioned need for details on textual aspects, there is a need for more clarification regarding individual differences factors and text processing in print or digitally. Simply stated, individual difference factors are the variations or deviations among individuals with regard to the characteristics shown to play a significant role in human learning and development (e.g., working memory, academic ability, gender; Gagné & Glaser, 1987). In the case of reading in print and digitally, individual difference factors such as reading rate, vocabulary knowledge, and topic knowledge have been shown to be particularly pertinent (Afflerbach, 2015; Luke, Henderson, & Ferreira, 2015). Surprisingly, very few studies in this review considered such relevant individual difference factors as fluency or topic knowledge as potential explanations for performance outcomes between print and digital reading (Kendeou et al., 2011). Thus, assessing the role of individual differences factors could help clarify patterns in comprehension performance across mediums.

Another area of concern throughout our review was *what* was measured within the studies. Although our criteria excluded studies that relied strictly on self-report data, this conservative filter still revealed shortcomings in measurement. For one, the majority (63.89%) of reading comprehension measures used were researcher developed. The psychometric properties of researcher-developed measures were often underreported and, even when reported, did not convey compelling evidence of strong validity and reliability. Furthermore, researcher-developed measures are generally configured specifically to the goals of the study, which can result in more favorable outcomes than would be realized from standardized or well-established indicators (Kimberlin & Winterstein, 2008). Minimally, this pattern of results calls for much more diligence among researchers investigating print and digital reading to be forthcoming about the psychometrics of all measures used, and to consider a variety of measurement tools including well-calibrated and well-established indicators of performance.

Moreover, interrogating the findings across studies in this review was difficult without detailed descriptions of comprehension measures including question format (i.e., multiple-choice or short constructed-response), scoring criteria, and item difficulty levels. For one, within the broader assessment literature, multiple-choice

questions often target the location and recall of specific information, whereas constructed-response questions can require participants to forge more complex inferences or to critique and evaluate the text (NAGB, 2008). However, because the majority of the studies employed multiple-choice measures, there were inadequate data to allow us to consider the differences by question format as we had intended.

In those instances when information on comprehension questions was delineated—whether research-developed or standardized and whether multiple-choice or constructed-response—the studies rarely examined different levels of comprehension (i.e., main idea or supporting details). In fact, only 8.33% of studies managed to probe comprehension on more than one level. In one study that incorporated multiple levels of comprehension (Singer & Alexander, 2017), the authors concluded that no significant differences in comprehension outcomes by medium emerged for larger grain size questions (e.g., identify the main idea). In contrast, when questions were more detailed or specific in nature (e.g., identify the supporting points), readers performed significantly better when reading in print. This finding suggests that looking only globally at comprehension outcomes when concerned about the role of reading medium may well mask important differences that can be seen only when the grain size of understanding is systematically assessed.

Beyond the concerns for format and level of comprehension assessment, there is another element to reading in print and reading digitally that merits consideration. Specifically, conducting this review led us to question another dimension that was often overlooked within the included studies—the nature of the task undertaken by participants. Because this review required all studies to have a measure of comprehension, participants were always engaging with an awareness that, minimally, their recall or interpretation of text content would be assessed. Within this review of the literature, it was rarely explicitly stated by the researchers how or if the task was communicated to the participants prior to reading. It has been documented that task demands influence both the processes and the products of text engagement (McCrudden, 2011; McCrudden, Magliano, & Schraw, 2010). As such, researchers need to be aware of the affordances and consequences that the tasks they devise have for participants, be detailed in their descriptions of those experimental tasks, and consider task features when interpreting their outcomes.

As this consideration of the nature of reading, the psychometric properties of study measures, learner characteristics, and the features of the task suggest, there are multiple factors influencing reading in print and digital forms that must be weighed in any emergent models of comprehension. Moreover, it is our contention that these factors operate in conjunction, and therefore they cannot be examined in isolation. For example, when we considered text length and question type as potential explanatory factors, we were able to unearth differences in comprehension by medium. In effect, when longer texts are involved or when individuals are reading for depth of understanding and not solely for gist, print appears to be the more effective processing medium (e.g., Lenhard et al., 2017; Mangen et al., 2013; Singer &Alexander, 2017).

Another example of this complexity was found when examining beginning readers between the ages of 5 and 6. These data revealed that when children of this age read simple texts, medium appears to have little influence on comprehension

outcomes (e.g., De Jong & Bus, 2004; Dundar & Akcayir, 2012). However, for readers of other ages, such as high school students, engaged in the processing of more complex texts, the findings suggest that medium type matters in comprehension (e.g., Eshet-Alkalai & Geri, 2009; Lenhard et al., 2017). For example, Lenhard et al. (2017) concluded that although participants read more quickly in digital medium, it led to a shallower processing of the text. In effect, under these circumstances, medium type plays a more significant role in comprehension outcomes. In future efforts to understand how text processing unfolds in print vis-à-vis digitally, researchers can either choose to ignore the complexity that confronts them or embrace it as part of a more comprehensive and integrated research design. It is our recommendation that the interplay of relevant factors should be routinely considered if researchers are attempting to fine-tune their understandings of the effects of reading in print and digitally for learning and performance.

Yet another unexplored area for future inquiry pertains to the form of digital device being employed. On a positive note, we unearthed a trend of an increasing number of studies choosing to examine the differences across multiple digital devices (e.g., De Jong & Bus, 2004; Tyner, 2014). In light of the continuing advancements in technology for reading digitally, this is a welcome change and one we would expect to see continue in the years to come. One reason we encourage this pursuit is that perhaps the differences that occur when reading in print and digitally are partly due to the neurocognitive processes instigated by particular features of digital devices. For example, visual legibility of digital texts, basic to word processing and comprehension, is influenced by several factors, including backlighting and luminance contrast (Stoop et al., 2013). By examining more than one digital device, researchers can better pinpoint the optimal conditions for reading digitally. Our field must endeavor to understand where the visual ergonomic differences across devices fit into the comprehension calculus.

In addition, future studies need to focus on capturing processing data. Such real-time measures of what is occurring while reading in print and digitally will offer critical information regarding the processing of text. For example, research has demonstrated that scrolling affects comprehension. As a case in point, Catalado and Oakhill (2000) found that comprehension is worsened when readers have to search from text that requires extended scrolling. Nonetheless, we have very few means of capturing the process of reading as it unfolds in real time.

It is important to highlight that this review was undertaken in the hope of serving as a starting point for theoretical models of reading comprehension that address critical dimensions such as learner differences, text characteristics, and task demands. As this systematic review has reinforced, there are basic learner differences that need to be incorporated in an emerging model of reading in print or digitally, including learners' age, their reading ability, and their relevant background knowledge. However, it is advisable that such models deal with these dimensions in interactive way. In addition to the aforementioned areas, medium must be factored into theoretical models. This review, in conjunction with other research, will help set the parameters for what may constitute a viable model in our field.

No matter how complex the question of reading across mediums may be, teachers and students must understand how and when to employ a digital reading device. It is fair to say that reading digitally is part and parcel of living and

learning in the 21st century. Nonetheless, there is unquestionably a place for print in schools and in the lives of students outside of school. For those invested in understanding and promoting student learning, therefore, there is little gained from setting up a false dichotomy between reading and digital reading. Consequently, we must arm ourselves with empirical evidence of *when*, *where*, and *for whom* greater benefits are accrued from reading in print, digitally, or in combination. Researchers should consider conducting a meta-analysis of the relevant literature in the future to further advance our knowledge on this topic.

Reading in print or digital form should not be horse race question. One medium will not and should not be regarded as routinely better for comprehension. Although the question regarding differences in comprehension across mediums is a complex one, we cannot turn a blind eye to its exploration, because digital texts are pervasive in students' and teachers' lives. Although Proulx (1994) may be unsettled by the ubiquity of digital reading devices present today, perhaps she was correct in her assessment of the timeless pleasure gained from reading a printed book. Both mediums appear to have a place in literacy and in learning that must be more fully appreciated.

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