No Negative Effects of Reading on Screen on Comprehension of Narrative Texts Compared to Print: A Meta-analysis

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ABSTRACT

While some argue digital reading media may impair text comprehension, the empirical literature is ambiguous, in particular when it comes to the reading of narrative texts. Therefore, a comprehensive and systematic meta-analysis of studies exploring the effect of screen reading media on reading comprehension of narrative texts was conducted (k = 32, N = 2239). Multimedia and interactive functions in general, the type of multimedia and interactive functions, the change in effect over time, and the type of digital reading device (computer, e-reader, and tablet) were explored as moderating variables. In general, the analyses did not reveal a significant impact of the reading medium (screen vs. paper) on the reading comprehension of a narrative text. Moreover, there does not seem to be a difference over time and between different types of digital reading devices. Also, the analysis of the subsample of studies using plain digital text without any additional functions in comparison to print showed no significant differences. In contrast, multimedia and interactive functions of digital texts affect reading comprehension positively, regardless of the type of additional function. In conclusion, the results do not suggest a negative effect of digital reading media on reading comprehension when reading narrative texts.

Reading is a vital skill, important for many aspects of our daily lives. Apart from educational settings, reading narrative texts for leisure is a key component of literacy. It is associated with better reading comprehension and uniquely contributes to a higher-level comprehension skill of inference-making (Duncan, McGeown, Griffiths, Stothard & Dobai, 2016; Torppa et al., 2020). Since leisure book reading is a major predictor of reading performance (Torppa, Eklund, Sulkunen, Niemi & Ahonen, 2018), observing changes in leisure reading behavior is essential. One of the main changes in recent years is the emergence and widespread use of digital texts in leisure time reading, partially replacing print reading. Even though the printed book is still a vital reading medium, the popularity of digital reading media is high (Khatri, 2020; Loh & Sun, 2019). Critics of digital reading argue that a digital reading device might disturb reading performance, in particular comprehension processes (e.g., Baron, 2015; Wolf, 2018).

Yet, the empirical literature presents inconclusive results. The dependency of reading comprehension on digital versus non-digital (i.e., print) reading media was the subject of a few meta-analyses in recent years (Clinton, 2019; Delgado, Vargas, Ackerman & Salmerón, 2018; Imel, 2018; Kong, Seo & Zhai, 2018). These generally claim that reading comprehension would be negatively affected by digital reading media. However, these prior meta-analyses mainly focus on academic reading and are not comprehensive concerning studies using narrative texts as stimuli, the most common text genre for
leisure reading. Accordingly, Kong, Seo and Zhai (2018) and Imel (2018) did not differentiate between text genres in their analyses. Clinton (2019) and Delgado, Vargas, Ackerman and Salmerón (2018) did separate their analyses by genre but only included studies with specific years of publication. Therefore, we argue that an additional meta-analysis of the existing literature is needed to come to a more comprehensive and thorough understanding of the effect of digital versus non-digital reading media on reading comprehension.

In our study, we explored the effect of digital reading exclusively for the reading of narrative texts and did so based on a meta-analysis of all relevant studies published over the past four decades. In addition to the main effects of reading medium on reading comprehension, which is at the heart of our analysis, we specify three factors that are argued to condition medium effects: multimedia and interactive functions, the differences of the effects over time, and different digital reading devices. Investigating the impact of these three factors provides more insights into the nuances of the reading medium’s effect on reading comprehension. The results of our analysis help to further understand general reading processes and the reading medium’s impact on leisure reading. Due to the progressing digitization of teaching materials, the results are especially important for educational researchers as well as practitioners.

Theoretical Background

Reading Narrative Texts on Screen

Even though narrative texts are an essential component in educational settings, they are primarily used for entertainment purposes (Martin-Chang, Kozak, Levesque, Calarco & Mar, 2021). Thus, studies interested in the effects of reading narrative texts often focus on the reception of narratives, and emotional and affective aspects. Comprehension, by contrast, is more commonly considered in studies looking at the effects of reading expository texts (e.g., Hebert, Bohaty, Nelson & Brown, 2016). However, as reading is an activity with the goal of decoding a text, reading comprehension is arguably the most crucial factor in narrative reading as well, and not only for expository texts (Oakhill, Cain & Elbro, 2015). Thus, as used in this article, reading comprehension describes a process of forming a suitable mental model based on understanding written words and sentences. This process includes literal as well as inferential comprehension of a text (Oakhill, Cain & Elbro, 2015).

Regardless of the respective facets of comprehension, four previously conducted meta-analyses consistently showed inferiority in reading comprehension of digital reading media compared to print (Clinton, 2019; Delgado, Vargas, Ackerman & Salmerón, 2018; Imel, 2018; Kong, Seo & Zhai, 2018). Digital reading media might trigger different reading processes than a printed book. More superficial reading strategies, like skimming and scanning, might be applied when reading books digitally rather than the deeper processing strategy learned for and by reading printed books (Baron, 2015; Wolf, 2018). However, the text genre is likely to condition this effect. In general, reading comprehension of narrative texts is better than reading comprehension of an expository text (Mar, Li, Nguyen & Ta, 2021). On the textual level, they consist of more connectives and present more temporal cohesion, both of which benefit reading comprehension (Graesser & McNamara, 2011). But also, when texts are framed as narrative texts, they are processed more slowly than texts framed as expository texts, which results in better memory for verbatim information and a better generation of inferences (Clinton et al., 2020; Zwaan, 1993). These findings can be explained by the higher emotional valence of a narrative text, which leads to more reading engagement and, therefore, to deeper processing and greater reading comprehension (Hamedi, Pishghadam & Fadardi, 2020). Thus, the deeper processing of the text might balance out the negative effect of a digital reading medium. Indeed, studies that also used text genre as a moderating variable in their meta-analysis painted a different picture of the impact of the reading medium on reading comprehension. Both Clinton (2019) and Delgado, Vargas, Ackerman and Salmerón (2018) showed a stable effect of the reading medium on reading expository texts.
However, neither of them replicated this finding with studies using narrative texts only. In their meta-analyses, they each used only seven samples, possibly limiting statistical power. Therefore, for our study that focuses on narrative texts only, the research question reads:

RQ1: Does reading comprehension differ when the same narrative text is read on a screen versus in print?

**Digital Reading Affordances**

An explanation for the growing popularity of digital reading could be that the device-specific affordances of digital reading media are more diverse than those of a printed book. The “conceptual definition of affordances – broadly described as possibilities for action – is the ‘multifaceted relational structure’ [...] between an object/technology and the user that enables or constrains potential behavioral outcomes in a particular context” (Evans, Pearce, Vitak & Treem, 2017, p. 36). Different types of screen devices, but also different types of e-books may offer very different “possibilities for action,” which, in turn, may affect reading comprehension.

Reading media differ primarily due to their different sensorimotor and cognitive affordances, which entails different forms of interaction and attention (Mangen, 2016; Schilhab, Balling & Kuzmicova, 2018). Multimedia devices like computers, tablets, and smartphones can be used for a broad range of different activities, while printed books and e-readers are designed simply for the purpose of reading. Digital reading devices offer specific functionalities, such as almost unlimited access to literature anywhere anytime or the possibility to enlarge the font size or to change the background light to the readers’ own preference. Further, they may present interactive functions such as hyperlinks to further information and dictionaries. Smartphones, tablets, and computers additionally offer multimedia additions but also functions distracting from the reading flow, like an internet browser, messengers, and other apps (D’Ambra, Wilson & Akter, 2019).

To explore the effect of digital reading media-specific affordances, we below elaborate on the relevance of three moderator variables for our analysis: multimedia and interactive functions, the differences of the effects over time, and different digital reading devices.

**Digital functions: Multimedia and interactive reading**

The affordances of digital reading media offer the possibility to include interactive and/or multimedia functions. It has been shown in other areas that such functions may contribute to learning (e.g., Greussing, Kessler & Boomgaarden, 2020). However, to our knowledge, prior research has not systematically quantified a summary effect of the impact of multimedia and interactive functions on reading comprehension in the area of reading narrative texts. Most of the meta-analyses mentioned above primarily included studies in which participants were presented the same plain text, once in print and once digitally on a screen. They, therefore, did not take media-specific affordances into account, which arguably are an important facet of digital reading media. For the present study, we deliberately decided to also include studies where the digital text is presented with additional functions. These additional functions include interactive and multimedia functions, like built-in dictionaries, pronunciation support, music, or animations. While we are well aware that interactive and multimedia functions are not identical and may elicit different responses (e.g., Takacs, Swart & Bus, 2015), for the purpose of this study, we needed to construct umbrella conceptualizations of affordances and therefore consider them in one variable. However, we differentiate between entertaining story-supporting functions, like animations, music, and sounds, and non-entertaining comprehension-supporting functions, like dictionaries and pronunciation support.

Digital reading was supplemented with additional functions already at an early stage. In the late 1980s, the first digital storybooks for children were developed. These did not only feature plain text shown on a screen but also multimedia functions, like word-by-word reading, as well as interactive functions, like a variety of small games (Chomsky, 1990). Over the years, the functions of computer-
supported storybooks were expanded to include multimedia options to, e.g., watch animations and listen to background music and sounds. Furthermore, readers can use interactive functions, like a virtual tutor reacting with feedback to their actions or use an advanced dictionary function (Bus, Takacs & Kegel, 2015).

However, it is not clear yet how those functions affect reading comprehension of a narrative text. Cognitive load theory suggests that working the memory can only process a certain amount of information, and splitting attention between different modes of information presentation could hinder comprehension (Chandler & Sweller, 1991). In favor of this theory, Lange (2019) reported that their participants’ immersion was disturbed by those additional functions. However, Plass, Heidig, Hayward, Homer, and Um (2014) found that positive emotions induced by a multimedia design fostered comprehension of informational material. Furthermore, Xu and Sundar (2016) described that the interactivity of a website affects the information processing of the interactive content positively and the information processing of the non-interactive content negatively.

Previous studies have suggested that it may not be the presence or absence of additional functions that makes the difference, but the type of the functions. In children, age 1–8 years old, print is outperformed by digital reading when the additional functions are content-related (Furenes, Kucirkova & Bus, 2021). Further multimedia functions benefit reading comprehension in preschool and primary school, while interactive functions seem to distract (Takacs, Swart & Bus, 2015). We contrasted studies using e-books offering entertaining functions additional to non-entertaining functions with studies that provided books with only non-entertaining comprehension supporting functions. Accordingly, our second research question is focused on the general effect of additional digital functions and the third on the effect of a specific type of digital functions:

RQ2: Does reading comprehension differ between reading narrative multimedia/interactive books and reading the same text in a printed version?

RQ3: Do different types of additional digital functions affect the reading comprehension differently compared to print when reading a narrative text?

Changes in reading comprehension on screen over the last decades

Over the last 40 years, the quality of digital reading media steadily increased with higher screen resolutions and faster information processing. Also, the use of digital reading media drastically increased while the novelty of the devices’ affordances decreased. One might think that with the advantage of enhancing technologies, more routine use of technology, and more digital experience, the print superiority in reading comprehension may decrease (Chen, Cheng, Chang, Zheng & Huang, 2014). In contrast, Kaufman and Flanagan (2016) argued that the experience with technology gained over the years could have a negative effect on comprehension. Learned habits, like skimming and quick scanning when reading digital, and therefore screen familiarity might lead to shallower reading. People might not mobilize the cognitive resources needed to sufficiently comprehend a text because they perceive a digital reading device as a platform for more superficial reading, like for checking e-mails and messages, and for reading shorter texts like news (Ackerman & Goldsmith, 2011).

No meta-analysis has, to our knowledge, studied the effect of reading on screen on especially narrative texts over a longer period of time. Still, by reviewing other meta-analyses on related topics, there is one that finds no effect (Kong, Seo & Zhai, 2018: investigated period 2001–2016, comparing studies published before and after 2013) and two that find a widening gap between print and digital reading (Imel, 2018: investigated period 1980–2016; Delgado, Vargas, Ackerman & Salmerón, 2018: investigated period 2000–2017). Following the two latter studies with a more similar range of publication years considered (i.e., Imel, 2018) as ours (i.e., 1982–2021) or a larger sample size (i.e., Delgado, Vargas, Ackerman & Salmerón, 2018), we explore whether the publication date has an effect. Thus, our fourth research question is:
RQ4: Did the reading medium’s effect on comprehension when reading a narrative text change over time?

**Different digital reading devices**
In addition to the computer, within the last two decades, new reading devices, like tablets, e-readers, and smartphones, have been introduced as digital reading media. It is commonly acknowledged that the affordances of a particular device condition media effects (e.g., Fox & McEwan, 2017). In line with the shallow reading hypothesis (e.g., Kaufman & Flanagan, 2016), different reading devices could vary in their effect on reading comprehension due to different affordances. While computers, tablets, and smartphones offer a range of functions, e.g., browsing the internet or messaging, e-readers are primarily designed as a digital version of a printed book, providing fewer distractions from the text (Sage, Piazzini, Downey & Masilela, 2020). Furthermore, the static file types like PDF (usually used on computers) affect reading comprehension differently than dynamic file types like EPUB (usually used on e-readers and in reading applications for smartphones and tablets). For example, the reading speed is higher when texts are read as EPUB compared to PDF (Zeng, Bai, Xu & He, 2016).

Primary studies on digital versus print reading and reading comprehension did test the effects of various types of digital reading devices. However, usually, only one screen type is included per study, and a comparative angle toward medium differences is rarely explored (exceptions are: Çınar, Doğan & Seferoğlu, 2019; Margolin, Driscoll, Toland & Kegler, 2013; Subrahmanyan et al., 2013). In their meta-analysis, Delgado, Vargas, Ackerman, and Salmerón (2018) did not find a significant difference between hand-held reading devices (tablet and e-reader) and computers in their effect on reading comprehension. However, in their analysis, they summarized the effects of reading on a tablet with reading on an e-reader. We, in contrast, decided to look at the two screen types separately because a tablet’s affordances with its multimedia purposes might be more similar to a computer’s affordances than an e-reader’s. Accordingly, the research question is:

RQ5: Do different digital reading devices differ in their effect on reading comprehension compared to print when reading a narrative text?

**Methods**

**Literature Search**
We collected the sample of studies used in the meta-analyses in three phases. First, we conducted an extensive literature search in the databases Scopus, PsycInfo, and Web of Science using the search strings “digital AND read*”, “screen AND read*”, and “digital AND print” and the keywords “eread*,” “kindle,” “tolino,” and “nook.” Second, to identify studies not detected by the database search, we performed a backward reference search by browsing the reference lists of the identified articles for further studies and a forward search by browsing the list of articles citing the identified articles in Google Scholar. Third, to find further eligible studies, we used the reference lists of the published meta-analyses by Delgado et al. (2018) and Clinton (2019). We also included gray literature, such as conference papers, dissertations, and master theses. The last search was conducted in February 2021. In line with reporting standards (Liberati et al., 2009), the complete sample selection process is shown in the PRISMA flow diagram (Figure 1).

**Inclusion/exclusion Criteria**
We included studies that reported a comparison of reading comprehension between reading the printed version and any digital version of the same text (between-participant or within-participant). Thus, we did not include effect sizes for comparisons of different screen types or different digital
reading modes and also excluded intervention studies in which either the participants in different conditions did not read the same texts or participants did not answer comprehension questions to a specific stimulus text. Furthermore, the stimulus material must have included at least one narrative text with an individual effect size for this text or text type. We therefore excluded studies using exclusively expository texts as stimulus. We also excluded effect sizes describing the relationship of the reading medium and reading comprehension of expository texts only or a combination of narrative and expository texts. Additionally, studies were excluded when the stimulus text featured the possibility of reader interference in the story, such as visual novels or text-based computer games. In contrast to the meta-analysis by Furenes, Kucirkova and Bus (2021), we only included studies where the participants read most of the text themselves and did not primarily listen to a second person or application reading the text aloud. Therefore, participants’ education level must have been at least the first grade of primary school, and participants had to have at least enough reading skills to read the stimulus material on their own. However, we did include studies where children listened to parts (but not all) of books with multimedia functions (e.g., when the spoken language is read aloud, or single words have a pronunciation support option).

To ensure at least some comparability in this heterogeneous sample, we included only studies using stimulus texts presented in the first language of most of the participants. We excluded qualitative research and case studies and set the minimum of the sample size to ten participants per experiment.
Coding Procedure

The data extraction of all the articles was done by two of the authors, resulting in independent observations for each article. Differences in coding were discussed until a consensus of 100% was reached. We coded the following key variables: study authors, publication year, additional multimedia/interactive functions (yes/no), type of additional functions (entertaining (e.g., animations, music) and non-entertaining functions (e.g., dictionaries, pronunciation support)/only non-entertaining comprehension supporting functions), screen type (computer, tablet, e-reader, smartphone, television), study design (between-participant, within-participant), type of publication (peer-reviewed publication, gray literature), sample size, sample age (1st–12th grade, university students, other adults; coded as primary school (1st–4th grade), secondary school (5th–12th grade), and adults (university students and other adults) and relevant effect sizes; and additionally, country in which the study was conducted, gender ratio, type of comprehension test (multiple choice, open questions, retelling; inferential questions, detailed questions, spatiotemporal questions), and the title of stimulus text (when no additional information was provided, it was coded as narrative text).

Sample

In total, 32 independent samples, published in 19 articles and 10 gray literature items, were included. The total sample size was N = 2239 with a mean of 69.97 (SD = 54.74), ranging from N = 19 individual participants to N = 284. In total, 66 effect sizes for the difference in reading comprehension between reading on screen and on paper were extracted. Even though we did not limit our search to English articles, the final sample consisted of articles written in English only. The data came from eleven countries, with 17 articles from North America, seven articles from Asia, and five articles from Europe. We included studies published between 1982 and 2021. When the relevant effect sizes were not reported in the published text or the supplemental material, authors were contacted to add the missing information. For further sample characteristics, see Table 1. The sample references are provided in the supplemental material.

Statistical Analyses

We converted the collected effect sizes into Cohen’s d (see supplementary material) using Comprehensive Meta-Analysis software Version 3 (Borenstein, Hedges, Higgins & Rothstein, 2014). A positive d-value describes a positive effect of the digital reading medium on comprehension compared to print. When more than two effect sizes were reported, e.g., effect sizes for more than one stimulus text, different types of questions, or different types of screens, all effect sizes were converted and used in the analysis.

For the analysis, we used the R package robustmeta (Fisher, Tipton & Zhipeng, 2017). Because most of the studies reported more than one effect size for the comparison of reading on screen and on paper, we conducted a robust variance estimation (RVE). With RVE, it is possible to include statistically dependent effect sizes in one meta-analysis without the loss of information and without the need to know the underlying covariance structure of the used effect sizes (Tanner-Smith, Tipton & Polanin, 2016). For all meta-analyses, we modeled meta-regressions with correlated effects and with small sample size corrections. We used ρ = .8 as an estimation for the correlation of effect sizes within a sample, which is the default option of robustmeta (alternative settings did not substantially alter the results). We conducted a meta-regression of the whole sample and five sub-samples (studies with and without additional functions and studies using a computer, e-reader, or tablet as digital reading medium) to analyze the effect of the different reading devices on reading comprehension. To examine heterogeneity, I² and τ² are reported. A positive mean effect size describes a better comprehension when the stimulus text is read on screen than in print.
| Study                                      | Type of publication | Study design | Study location    | Sample size | Age group | % women/girls | Type of digital reading device | Type of multimedia functions | Type of additional function | Stimulus text                                                                 | Type of comprehension test                                                                 |
|-------------------------------------------|---------------------|--------------|-------------------|-------------|-----------|---------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| Cavalli et al. (2019), sample 1 Journal   | Journal             | Within       | France            | 30          | University| 60            | E-reader                      | No                           | -                             | Demièrjournée (Last day); Bats-toi, ma belle (Girl, don't give up!)             | Open questions (OQ) & sorting: literal & inferential & spatiotemporal                     |
| Cavalli et al. (2019), sample 2 Journal   | Journal             | Within       | France            | 30          | University| 60            | E-reader                      | No                           | -                             | Demièrjournée (Last day); Bats-toi, ma belle (Girl, don't give up!)             | QQ & sorting: literal & inferential & spatiotemporal                                      |
| Chen and Chen (2014)                       | Journal             | Between      | Taiwan            | 53          | 5th grade | 49.06         | Computer                      | Yes                          | Non-entertaining only          | An unbelievable night; Pufflings                                               | Multiple choice questions (MC), OQ, fill-in-the-blanks: literal & inferential              |
| Çınar et al. (2019), sample 1 Journal     | Journal             | Between      | Turkey            | 63          | 5th–8th grade | 100          | Smartphone, tablet, computer | No                           | -                             | Narrative text                                                            | MC: inferential & literal                                                                |
| Çınar et al. (2019), sample 2 Journal     | Journal             | Between      | Turkey            | 64          | 5th–8th grade | 0            | Smartphone, tablet, computer | No                           | -                             | Narrative text                                                            | MC: inferential & literal                                                                |
| Doty et al. (2001)                        | Journal             | Between      | United States of America (USA) | 39          | 2nd grade | 51.28         | Computer                      | Yes                          | Non-entertaining only          | Thomas’ Snowsuit                                      | OQ & Retelling: literal & inferential                                                  |
| Duran and Alevli (2014)                    | Journal             | Within       | Turkey            | 74          | 8th grade | Not mentioned | Computer                      | No                           | -                             | Narrative text                                                            | OQ: literal & inferential                                                               |
| Ertem (2009)                              | Dissertation       | Between      | USA               | 51          | 4th grade | 62.3          | Computer                      | Yes                          | Entertaining and non-entertaining | Sheila Rae, the Brave; Arthur’s Teacher Trouble Ramona Quimby: Age 8 | MC & retelling                                                                 |
| Grace (2011)                              | Master thesis       | Within/between | USA               | 19          | 3rd grade | Not mentioned | Tablet                        | Yes                          | Non-entertaining only          |                                                                                  |                                                                                  |
| Study                                      | Type of publication | Study design | Study location | Sample size | Age group | % women/girls | Digital reading device | Interactive and/or multimedia functions | Type of additional function | Stimulus text                                                                 | Type of comprehension test |
|--------------------------------------------|---------------------|--------------|----------------|-------------|-----------|---------------|------------------------|------------------------------------------|------------------------------|--------------------------------------------------------------------------------|----------------------------|
| Greenelee-Moore and Smith (1994)           | Conference paper    | Between      | USA            | 31          | 4th grade  | Not mentioned | Computer               | Yes                                      | Entertaining and non-entertaining | Thomas’ Snowsuit; The Paper Bag, Princess; Mud Puddle; Heather Hits her First Home Run; Moving Gives Me A Stomachache; The Tale of Benjamin Bunny; The Tale of Peter Rabbit | MC: literal, vocabulary, inferential |
| Grimshaw et al. (2007), study 1            | Journal             | Between      | United Kingdom | 51          | Primary school | Not mentioned | Computer               | Yes                                      | Entertaining and non-entertaining | - The Little Prince | MC & OQ: literal & inferential |
| Grimshaw et al. (2007), study 2            | Journal             | Between      | United Kingdom | 55          | Primary school | Not mentioned | Computer               | No                                       | - Narrative texts               | MC: literal & inferential |
| Halamish and Elbaz (2020)                  | Journal             | Within       | Israel         | 38          | 5th grade   | Not mentioned | Computer               | No                                       | - Masafat                     | MC: literal |
| Hermena et al. (2017)                      | Journal             | Within       | United Arab Emirates | 24 | University | Not mentioned | Tablet                 | No                                       | - Narrative texts               | MC: literal & inferential |
| Hsiao and Chen (2015)                      | Journal             | Between      | Taiwan         | 60          | 3rd grade   | 36.67         | E-reader               | Yes                                      | Entertaining and Missing Grandmother | MC |
| Jeong (2012)                               | Journal             | Within       | South Korea    | 56          | 10–12 years old | 48.21         | Computer               | No                                       | - Narrative texts               | MC |
| Kaufman and Flanagan (2016)                | Conference paper    | Between      | USA            | 81          | Adults      | 58.02         | Computer               | No                                       | - Narrative texts               | MC: literal & inferential |
| Mangen et al. (2019)                       | Journal             | Between      | France         | 50          | Adults      | 64            | E-reader               | No                                       | - Lusting for Jenny, Inverted | MC: literal & inferential & spatiotemporal |
| March (1999)                               | Master thesis       | Within/ between Canada | 25      | 3rd grade | 56          | Computer               | Yes                                      | Entertaining and Thomas Snowsuit; Northern Lights: The Soccer Trails | OQ: literal & inferential |
| . Margolin et al. (2013)                   | Journal             | Between      | USA            | 90          | University | 74.44         | E-reader, computer     | No                                       | - Narrative text                | MC: inferential |

(Continued)
| Study                                | Type of publication | Study design | Study location | Sample size | Age group | % women/girls | Digital reading device | Interactive and/or multimedia functions | Type of additional function | Stimulus text                                                                 | Type of comprehension test |
|-------------------------------------|---------------------|--------------|----------------|-------------|-----------|--------------|------------------------|----------------------------------------|-------------------------------|--------------------------------------------------------------------------------|----------------------------|
| Margolin et al. (2018)              | Journal             | Within       | USA            | 60          | University | 66.67        | E-reader               | No                                     | -                             | Narrative text                                                                 | MC: literal, inferential     |
| Matthew (1997), study 1             | Journal             | Between      | USA            | 74          | Primary school | 54.05        | Computer               | Yes                                    | Entertaining and Arthur’s Teacher Trouble; Mud Puddle; Arthur’s Birthday Sounder | MC & OQ: literal & inferential |
| McCrea-Andrews (2014)               | Dissertation       | Between      | USA            | 36          | 6th grade  | 55.56        | E-reader               | Yes                                    | Non-entertaining only          | Dogs of Riga; Bloodwork; MC: literal & inferential                             |
| Moyer (2011)                        | Dissertation       | Within       | USA            | 66          | University | 100          | E-reader               | No                                     | -                             | Fatally Flaky; The Complete Works of Saki                                      | MC                          |
| Muter et al. (1982)                 | Journal             | Between      | Canada         | 32          | Adults     | Not mentioned | Television            | No                                     | -                             | Sounder                                                                       | MC                          |
| Pearman (2008)                      | Journal             | Within       | USA            | 54          | 2nd grade  | 46.3         | Computer               | Yes                                    | Entertaining and Mud Puddle; Moving Gives Retelling non-entertaining Me a Stomachache; Thomas’ Snowsuit, The Paper Bag Princess; Heather Hits Her First Home Run; A Long Hard Day on the Ranch | MC                          |
| Rasmusson (2014)                    | Journal             | Within       | Sweden         | 117         | 14–15 year olds | 54.7         | Computer               | No                                     | -                             | Fox; Mute                                                                      | MC                          |
| Schwabe et al. (2021)               | Journal             | Between      | Austria        | 207         | Adults     | 81.16        | E-reader               | No                                     | -                             | Schönle Freunde (Nice friends)                                                | MC, OQ, sorting: literal & spatiotemporal |
| Seehafer (2014)                     | University Journal | Between      | USA            | 67          | University | Not mentioned | Computer               | No                                     | -                             | The Men of Brewster PlaceMC                                                   | MC                          |
| Stevens (2014)                      | Dissertation       | Between      | USA            | 284         | 7th & 8th grade | 47.89        | Computer               | Yes & no                              | Non-entertaining only            | The Masque of the Red Death                                                   | MC                          |
| Subrahmanyam et al. (2013)          | Journal             | Between      | USA            | 120         | University | 50           | Computer, tablet       | No                                     | -                             | Narrative text                                                                | MC: literal, inferential     |
| Wells (2012)                        | Dissertation       | Between      | USA            | 138         | 6th–12th grade | Not mentioned | Tablet                | No                                     | -                             | Chasing Lincoln’s Killer: The search for John Wilkes Booth                    | MC                          |
Additionally, we repeated the meta-regression analysis using the whole sample with the for the research question relevant variables publication year, additional digital functions, and digital reading device type, and with the control variables publication type, study design, and sample age-group as moderators. To further investigate the effect of different additional functions, we conducted a meta-regression with only the studies with additional functions as sample and the type of function (entertaining and non-entertaining functions or non-entertaining comprehension supporting functions only) as moderators. As study-design did not turn out to be a significant moderator, we did not split our sample in different analyses for within-participant and between-participant design studies. To check for a possible publication bias, we used an Egger Sandwich test. The Egger Sandwich test combines Egger’s regression test with RVE and is therefore suitable for models with dependent effect sizes (Rodgers & Pustejovsky, 2021). Further, because the estimation of the correlation of the effect sizes was set to the arbitrary $\rho = .8$, we also conducted the analyses with $\rho = 0, \rho = .2, \rho = .4, \rho = .6, \rho = 1$ to examine how sensitive the model was to differing $\rho$-values. Due to the non-significant result of the main analysis, we used the TOSTER R package (Lakens, 2017) to conduct two one-sided tests to examine the equivalence of the result to zero with the lower and upper bound set to $d = −0.25$ and $d = 0.25$ and a null hypothesis test. For all analyses, the level of significance was set to $p = .05$.

**Results**

**Overall Analysis**

In RQ1, we asked if the reading comprehension differs when the same narrative text is read on a screen versus in print. The results of the meta-analysis using the whole sample ($k = 32$) do not suggest a significant difference in reading comprehension of a narrative text between reading an e-book and reading in print ($d = 0.10$, $SE = 0.06$, $p = .12$, 95% CI $[−0.03, 0.22]$). However, the heterogeneity was high ($I^2 = 74.25\%$, $r^2 = 0.10$). The first moderator analysis showed that neither the primary study design nor the type of publication significantly influenced the observed effect (see Table 2).

**The Effect of Additional Multimedia/interactive Functions**

In RQ2, we asked if reading comprehension differs between reading narrative multimedia/interactive books and reading the same text in a printed version. The moderator analysis using the whole sample showed a significant difference in reading comprehension between reading stimuli with and without multimedia/interactive functions (see Table 2). The subgroup analyses revealed that the reading medium does not affect the comprehension of a narrative text when the e-book version does not contain interactive or multimedia functions, thus is more similar to the printed book. When there are no multimedia functions or additional support ($k = 21$), such as dictionaries, added to the text, the effect of the reading medium on reading comprehension is almost zero and not significant ($d = −0.02$, $SE = 0.06$, $p = .67$, 95% CI $[−0.14, 0.09]$, $r^2 = 0.07$, $I^2 = 71.40\%$). However, when multimedia or interactive functions are present ($k = 12$), the positive effect of the digital reading medium on comprehension is small but significant ($d = 0.37$, $SE = 0.11$, $p < .01$, 95% CI $[0.13, 0.61]$, $r^2 = 0.12$, $I^2 = 69.15\%$), indicating that multimedia/interactive functions aid reading comprehension when the stimulus is a narrative text. However, while the sample age group was not a significant factor (see Table 2), it needs to be mentioned that all primary studies using multimedia/interactive functions were conducted on school children (2nd–12th grade). This may mean that reading comprehension skills are embedded in the school and learning context and might be, therefore, measured and tested differently than in studies on adults (e.g., different texts and test complexities and group vs. single testing situations).
Our RQ3 was if different types of additional digital functions affect the reading comprehension differently compared to print when reading a narrative text. Nevertheless, the moderator analyses using the additional functions sub-sample revealed no difference in reading comprehension when additional to the reading supporting functions, like dictionaries or pronunciation functions, entertaining multimedia functions, like animations, sound effects, and/or sound effects, were implemented in the digital version of the text compared when only reading supporting, non-entertaining functions were present ($b = 0.07, SE = 0.20, p = .74, 95\% CI [−0.40, 0.54])$.

**Change of Effect over Time**

The RQ4 was if the reading medium’s effect on comprehension when reading a narrative text changed over time. The moderator analysis did not show a significant effect of the publication year on the reading medium’s impact on reading comprehension (see Table 2). Therefore, the reading medium’s effect on reading comprehension of a narrative text seems not to be affected by the publication year and, thus, did not change significantly over time.

**Different Digital Reading Devices**

The last research question, RQ5, was if different digital reading devices differ in their effect on reading comprehension compared to print, when reading a narrative text. The moderator analysis did not show a significant difference in the effect on reading comprehension between the different reading devices, computer, tablet, e-reader, smartphone, and television, in comparison to print (see Table 2). The reading device computer did not significantly differ in its effect on reading comprehension compared to print ($d = 0.06, SE = 0.08, p = .45, 95\% CI [−0.11, 0.23], \tau^2 = 0.10, I^2 = 75.27\%)$. Furthermore, neither a tablet ($d = 0.04, SE = 0.03, p = .29, 95\% CI [−0.07, 0.16], \tau^2 = 0.00, I^2 = 0.00\%$) nor an e-reader ($d = 0.14, SE = 0.12, p = .28, 95\% CI [−0.14, 0.43], \tau^2 = 0.15, I^2 = 81.27\%$) differed significantly in its effects on reading comprehension compared to reading in print.

**Publication Bias**

When used on the whole sample, the Egger sandwich test did show a significant effect ($β = 1.29, SE = 0.60, p = .02$). However, the detected funnel plot asymmetry could have another cause than a publication bias (Rodgers & Pustejovsky, 2021). Moreover, given that the difference in effect between the peer-reviewed studies and the gray literature was not significant (see Table 2) and the fact that only 21 of the 66 effect sizes used in the meta-analysis were significant, a publication bias, which affects the non-significance of the summary effect, is not likely.

**Robustness of Results**

The results of the analyses with differing estimated correlation values for the dependent effect sizes showed that the models were not sensitive to different $\rho$-values. At least up to the third decimal place, the results of all analyses were identical regardless of $\rho$. Thus, the chosen $\rho$-value of $\rho = .8$ did not influence the results. Further, the equivalence test and the null hypothesis test suggested the observed main effect was statistically equivalent to zero (lower bound: $Z = 5.80, p < .001$; upper bound: $Z = −2.55, p < .01$) and not different from zero ($Z = 1.62, p = .10$). We can therefore conclude that in case, and contrary to our results, the effect of a reading medium on comprehension of narrative texts does exist, it is too small to be relevant.
Discussion

In this article, we explored the impact of digital reading media on reading comprehension compared to print when reading narrative texts. In contrast to Imel (2018) and Kong, Seo, and Zhai (2018), we did not find a negative association of digital reading devices with reading comprehension. However, in their analyses, they did not differentiate between text genres and, thus, also included effects of studies using expository texts. Nevertheless, in line with the meta-analyses by Clinton (2019) and Delgado, Vargas, Ackerman, and Salmerón (2018), yet with a sample consisting of almost five times as many samples as their analyses, we also did not find a significant general effect of the reading medium on reading comprehension when reading a narrative text. Even after excluding studies using e-books with additional multimedia/interactive functions for the respective treatment groups, the results did not change much. Therefore, we did not confirm the apprehension of critics of digital reading like Baron (2015) and Wolf (2018), who give cause to consider that digital reading media could diminish the reading performance. In contrast, our results suggest a small advantage of the narrative text’s digital version compared to the printed text when multimedia/interactive functions were used. We found a positive association of multimedia/interactive functions on reading comprehension when children read themselves, suggesting that multimedia/interactive functions are more supportive for comprehension than distracting. These findings foster the hypothesis that positive emotions evoked by multimedia functions and interactive information processing support comprehension (Pliss, Heidig, Hayward, Homer & Um, 2014; Xu & Sundar, 2016). Previous reviews with meta-analyses (Furenes, Kucirkova & Bus, 2021; Takacs, Swart & Bus, 2014; Zucker, Moody & McKenna, 2009) investigating the impact of interactive and multimedia functions on story comprehension focused mainly on children without the ability to read themselves. Furthermore, they included very diverse studies in terms of treatment and control conditions, making it difficult to extract the effect of multimedia/interactive reading. However, they also showed that multimedia/interactive storytelling positively affects story comprehension in children. Additionally, our results are in line with a similar meta-analysis conducted by Clinton-Lisell, Seipel, Gilpin, and Litzinger (2021). In their meta-analysis, they found a positive association between interactive reading and reading comprehension when reading an expository text. Therefore, we conclude that digital reading does not negatively affect reading comprehension when reading narrative texts but can even affect it positively due to multimedia/interactive enrichments. However, in contrast to Takacs, Swart, and Bus (2015), who also reported a positive effect of multimedia functions on comprehension but also showed no significant effect of interactive functions, we did not find a difference between different types of additional functions in their effect on comprehension.

The expectation (RQ4) that increased familiarity with digital media may moderate a possible negative effect of a digital reading device (Çınar, Doğan & Seferoğlu, 2019; Margolin, Driscoll, Toland & Kegler, 2013) did not hold because our results suggest that the effect of digital reading media on reading comprehension did not linearly change over time. Thus, theories, suggesting either a positive or negative change in this effect, were not confirmed. Neither better screen technology nor shallow reading processes learned in other contexts led to a change in the reading medium’s effect on reading comprehension.

Moreover, we also did not find a difference between the different digital reading media in their effect on narrative reading comprehension. Çınar, Doğan, and Seferoğlu (2019) explained that the cognitive load between reading various digital reading devices and in print might be different due to small screens with different fonts, brightness, and colors affecting attention and visual perception, and Hermena et al. (2017) suggested that reading comprehension might be the same when the conditions, like luminance and contrast, are controlled for. Furthermore, we argued in an earlier article that e-ink technologies might not be inferior to paper regarding legibility. As e-readers are solely designed for reading, they might not trigger shallow reading like other digital reading devices, which are often used for skipping and scanning like a computer screen or tablet (Schwabe, Brandl,
Table 2. Meta regression results (whole sample).

|                                | b (SE)     | t (df) | p     | 95% CI [lower, upper] |
|--------------------------------|------------|--------|-------|-----------------------|
| Intercept                      | 2.74 (37.34) | 0.07 (8.94) | .94     | [−81.82, 87.29]       |
| Additional functions yes       | 0.35 (0.13)   | 2.76 (4.28) | .047   | [0.01, 0.69]         |
| Year of publication            | 0.00 (0.02)    | −0.08 (8.94) | .94     | [−0.04, 0.04]        |
| Reading device e-reader         | 0.27 (0.14)    | 2.00 (11.64) | .07     | [0.23, 0.57]         |
| Reading device tablet          | 0.04 (0.16)    | 0.25 (4.51)   | .022   | [−0.38, 0.46]        |
| Reading device smartphone      | 0.22 (0.17)    | 1.26 (1.22)    | .40     | [1.23, 1.67]         |
| Reading device television      | 0.37 (0.64)    | 0.57 (8.16)    | .58     | [1.11, 1.84]         |
| Within-participant design      | 0.09 (0.11)    | 0.85 (12.24)   | .41     | [0.14, 0.32]         |
| Publication in a peer-reviewed journal | −0.13 (0.11)  | −1.13 (11.21)  | .28     | [0.38, 0.12]         |
| Age group primary school       | 0.22 (0.27)    | 0.83 (6.81)    | .43     | [0.41, 0.86]         |
| Age group secondary school     | 0.18 (0.14)    | 1.24 (10.66)   | .24     | [0.14, 0.50]         |

k = 32; Moderators (Number of conditions and not independent sample show): additional functions (no: k = 21, yes: k = 12), year of publication, reading device (computer: k = 20, e-reader: k = 9, tablet: k = 6, smartphone: k = 2, television: k = 1), study design (between-participant design: k = 22, within-participant design: k = 10), type of publication (gray literature: k = 10, peer-reviewed journal: k = 22), age group (adults: k = 12, primary school: k = 10, secondary school: k = 10).

Boomgaarden & Stocker, 2021). However, these arguments are not sustainable as we did not find a significant difference in the impact on reading comprehension between any digital reading device compared to print.

In conclusion, the negative impact of reading on screens on reading comprehension is not present when reading narrative texts. Therefore, the genre “narrative text” probably compensates for a negative effect of digital reading media on the reading process, as shown for expository texts (e.g., Clinton, 2019; Delgado, Vargas, Ackerman & Salmerón, 2018). However, there are contradicting hypotheses as to how narrative texts affect reading from screen. On the one hand, the cognitive load of reading a narrative text might be smaller than when reading an expository text. Therefore, the reader might still have enough cognitive capacity to efficiently process the text even if additional resources are needed when reading digitally (Rasmussen, 2014; Margolin, Snyder & Thamboo, 2018). On the other hand, the mind-set of reading a narrative text might trigger a more attentive reading process compared to reading an expository text. The reader must stay alert during the act of reading because every detail of a text might be vital to the story. However, the importance or unimportance of these details reveals itself only after the story progresses and not necessarily at the moment at which the details are read (Zwaan, 1993). Thus, due to attentive reading, the effect of the reading medium might lose its strength. Moreover, with immersion in a story, the surroundings might become less relevant, and the reader could be less aware of the reading medium they are using (Green & Brock, 2000; Kuzmičová, 2014). However, more research is needed to clarify this contradiction.

Alternatively, the reason why we did not find a significant effect of the reading medium on reading comprehension of a narrative text might be due to insufficient research methods used in the primary studies. The effect might be too small to be measurable with the given instruments (Margolin, Driscoll, Toland & Kegler, 2013; Subrahmanyan et al., 2013). Additionally, most studies with a narrative text as stimuli used reading comprehension tests designed to measure reading comprehension regardless of text genre, which translates to expository texts being the default. These instruments might not be suitable for researching reading comprehension of narrative texts, and new methods need to be developed. Genre-specific properties like character development, chronology, and the situation model might need to be brought into the focus of further research more than literal comprehension questions.

This meta-analysis study is not without limitations. Since all studies incorporated into the meta-analyses regarding multimedia/interactive functions used school students as samples to investigate the effect of digital multimedia/interactive reading on reading comprehension, we cannot make any statements regarding the effect on more skilled readers. Further, we cannot differentiate if entertaining functions on their own affect reading comprehension because, in our sample, they were mostly paired with comprehension supporting functions, like dictionaries and pronunciation support.
Moreover, even if second language learners probably benefit most from multimedia/interactive functions like a dictionary, we did not include second language learners in this analysis. This could also be especially important for not only narrative texts but also expository texts used for studying. Additionally, other individual differences besides the first language could play a role in the digital reading of narrative texts, like gender, working memory, personality, and preferences for a specific reading medium (Duran & Alevli, 2014; Guarisco, Brooks & Freeman, 2017; Hou, Wu & Harrell, 2017; Rasmusson, 2014; Margolin, Snyder & Thamboo, 2018). However, more research is needed to make a statement about individual differences. Additionally, the primary studies used in the meta-analyses conducted their reading comprehension tests directly after reading. Therefore, we cannot make any assumptions about the long-term effects of digital reading media on reading comprehension.

More research is needed regarding the effect of smartphones on reading comprehension. Due to the lack of studies, we were not able to conduct a meta-analysis on the effects of reading narrative texts on a smartphone. This is especially unfortunate because smartphones are becoming a more popular device for reading texts (Loh & Sun, 2019). Especially with the smartphone, there is a constant chance of getting distracted during reading, which could greatly affect the reading process. Most of the studies were conducted in controlled lab or school settings, ideal for reading without medium-specific disturbances, like the possibility to access the internet or getting messages on the same device. Future research should therefore also concentrate on studying the effect of the reading medium on reading comprehension with more external validity.

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**Data Availability Statement**

The data described in this article are openly available in the Open Science Framework at [https://osf.io/gsut9/](https://osf.io/gsut9/).

**Open Scholarship**

This article has earned the Center for Open Science badges for Open Data and Open Materials through Open Practices Disclosure. The data and materials are openly accessible at [https://osf.io/gsut9/](https://osf.io/gsut9/).

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