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Teaching with Tech or Text? A Meta-Analysis for Evidence-Based Reading Instruction

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ABSTRACT

Background. The rapid integration of digital reading in higher education has changed how students engage with academic texts. Conflicting evidence remains on whether digital formats support reading comprehension as well as print. This gap matters given the growing reliance on screen-based learning and the cognitive demands of academic reading..

Purpose. This meta-analysis examined whether technology-enhanced reading improves comprehension compared to print among undergraduate students. The study addressed three aspects: (1) overall differences in comprehension between digital and print formats, (2) variations across pre-, during-, and post-COVID periods, and (3) the moderating role of text modality (text-only vs. multimodal).

Method. Following PRISMA guidelines, this study synthesised data from 13 empirical studies published between 2017 and 2025, involving 1,029 undergraduate students across L1, L2, and EFL contexts. Effect sizes were calculated using Hedges' g within a random-effects model. Subgroup and meta-regression analyses were conducted to examine moderating variables.

Results. The findings showed a small but statistically significant advantage for print reading over digital formats ($g = 0.265$, $p < .001$). This advantage was more pronounced in post-pandemic studies ($g = 0.333$) and in text-only materials ($g = 0.291$), while multimodal texts showed greater variability. Meta-regression indicated no significant change in effect size over time, and publication bias was minimal. Print reading consistently supported deeper comprehension, particularly for cognitively demanding academic texts.

Conclusion. Print yields stronger comprehension than digital formats in undergraduate reading, especially for complex academic texts. This meta-analysis informs teaching practice by recommending print for high-stakes reading and metacognitive scaffolding when digital formats are used.

KEYWORDS

Cognitive Load, Digital Reading, Higher Education, Meta-Analysis, Print Comprehension

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INTRODUCTION

Evidence-based instructional practice has become a pressing concern in higher education, as universities work to strengthen academic literacy and critical reading among undergraduates. A substantial body of research indicates that many college students lack the advanced comprehension techniques required to navigate complex

academic content (Ahmed, 2021; Gao and Gan, 2020; Talwar et al., 2022; Wong and Li, 2023). This deficit is consequential because reading competency develops unevenly across the transition from secondary to tertiary education, with many first-year students arriving underprepared for the demands of university-level texts (Ntereke and Ramoroka, 2017).

The shift from print to digital reading has reshaped how students interact with academic texts, including how they annotate, highlight, and navigate (Inie et al., 2021; Hargreaves et al., 2022). Over the past decade, higher education has incorporated screen-based materials into the curriculum, exposing students to substantial amounts of digital academic content in their regular coursework (Raible et al., 2015). Although digital reading offers convenience and accessibility, mounting evidence suggests that print can foster comparable or better comprehension (Baron, 2017; Singer and Alexander, 2017). Multiple studies further report that on-screen reading is associated with shallower processing and weaker understanding, particularly for cognitively demanding texts (Khan, Ajani, and Enakrire, 2023; Liao, Yu, Kruger, and Reichle, 2024). Multitasking and ambient distraction in digital environments compound these effects by disrupting concentration and deep cognition (Dontre, 2021; Pedro, Barbosa, and Santos, 2018). These concerns have intensified since the COVID-19 pandemic, which accelerated reliance on screen-based learning and made the question of medium effects far more consequential for everyday instructional decisions (Coiro, 2021).

The empirical picture remains divided. Some studies report that screen-based reading harms comprehension through distraction and surface-level processing (Clinton, 2019; Khan, Ajani, and Enakrire, 2023). Others contend that interactive features, searchability, and multimedia integration in digital platforms can support, and may even enhance, understanding, especially for students already accustomed to online reading (Schwabe et al., 2022). These competing findings indicate that medium effects are neither uniform nor straightforward; they are contingent on learner characteristics, instructional context, and task complexity. Educators, instructional designers, and policymakers need an evidence-based framework that moves beyond aggregate comparisons and identifies precisely the conditions under which each medium best supports learning.

Existing meta-analyses fall short of providing such a framework in three specific respects. Most prior syntheses (Delgado et al., 2018; Clinton, 2019; Kong et al., 2018) pool effects across primary, secondary, and tertiary learners, thereby obscuring patterns specific to undergraduates, whose reading demands and cognitive resources differ substantially from those of younger readers. More recent meta-analyses (Schwabe et al., 2022; Li and Yan, 2024) report aggregate medium effects without systematically examining how the COVID-19 pandemic has reshaped the relationship between medium and comprehension, despite this period representing a watershed moment for digital learning. The moderating role of text modality, whether text-only or multimodal, has received uneven attention. This omission is striking. Theories of multimedia learning (Mayer, 2014) predict that this very distinction is central to any pedagogical recommendation. Instructors lack guidance on when, for whom, and for what kind of text each medium is most effective.

The present meta-analysis directly addresses each of these gaps. It synthesises empirical research conducted between 2017 and 2025, a window chosen to span the pre-, during-, and post-COVID periods. The review restricts inclusion to undergraduate students in higher education and conducts subgroup analyses on text modality to test whether the digital-print gap varies with text type. The studies reviewed span first-language (L1), second-language (L2), and English as a foreign language (EFL) contexts, with learner language background treated as a contextual feature rather than an analytical moderator. Each of the three research questions below maps directly onto one of the gaps identified above. The first isolates the digital-print effect within the undergraduate

population, addressing the population gap. The second examines temporal variation across pandemic periods, addressing the temporal gap. The third tests whether text modality moderates the effect, addressing the modality gap. The review is organised around three research questions, each formulated as a direct response to one of the gaps identified above:

1. Does technology-enhanced reading improve comprehension over print for undergraduate students in higher education?
2. Do digital and print comprehension outcomes differ across pre-, during-, and post-COVID periods in higher education?
3. Does text modality (text-only vs. multimodal) moderate the digital-print comprehension gap among undergraduates?

Literature Review

Reading Comprehension in Higher Education

University-level reading demands extend well beyond functional literacy, requiring advanced analytical, interpretive, and critical capacities. A developmental threshold has been identified where readers must move from passive, memory-focused processing to an active stance that integrates new information with existing knowledge structures (Bergman, 2024; Grabe, 2016). Achieving this shift requires recognising that texts are situated within particular discourse communities whose claims are interrogated from multiple vantage points. Faculty across disciplines share responsibility for cultivating such expertise (Horning, 2022). Assigning readings alone will not foster the requisite depth of comprehension. Compounding the challenge, many students arrive at university with limited exposure to complex texts and instructional practices confined to literal comprehension, widening the gap between secondary preparation and higher-education expectations (Orellana et al., 2024; Yulia et al., 2020; Anggraini et al., 2022). Screen-based reading disadvantages lower-skill readers more sharply than their higher-skill peers, reinforcing the need for differentiated instructional strategies (Holsey Foss et al., 2025).

Reading comprehension poses a persistent hurdle for many university students, especially as they confront the rigorous demands of academic coursework. Undergraduates often feel anxious about allocating enough time for extensive reading and about understanding dense material (Bergman, 2024; Castles et al., 2018; Edwards et al., 2023; Spitzer et al., 2021; Suhartoyo et al., 2025). Students struggle to shift from passive consumption to active engagement with texts, a transition that underpins effective writing, questioning, and participation in lectures and seminars. Critical reading instruction remains an urgent yet underaddressed priority in higher education, despite clear evidence of widespread reading difficulties (Horning, 2022; Grabe and Yamashita, 2023). Proficient reading is essential for academic success, and faculty express concerns about pervasive skill deficits across diverse national contexts (Orellana et al., 2024; Bury, 2016). Comprehension challenges have been linked to the rapid digitalisation of academic reading tasks, emphasising that students' critical-reading development must now occur across both print and digital modalities (Li, 2024). Building on these challenges in students' academic literacy, recent scholarship has examined how the medium of reading, whether print or digital, shapes comprehension processes and learning outcomes in higher education.

Reading Comprehension in Digital Environments

This subsection examines empirical evidence comparing comprehension outcomes across digital and print reading formats in response to the growing focus on modality and literacy. The increasing integration of digital reading in higher education has led to extensive research comparing comprehension outcomes between digital and print formats. Several studies and meta-analyses

show a consistent, modest advantage for print reading, especially when students engage with longer or more complex academic texts. Students reading in print performed better on comprehension tasks than those reading digitally, with the benefit being more pronounced under time constraints (Delgado et al., 2018). University students achieved higher comprehension scores when using print materials, particularly for informational content (de-la-Peña et al., 2024). This pattern has also been reported in domain-specific contexts such as health sciences, where students better understood content-dense texts when reading from paper (Lavoie et al., 2021). These findings suggest that while digital reading offers practical advantages, print remains slightly more effective in supporting deep comprehension within higher education.

Print yields stronger comprehension than screens for three reasons. First, screens encourage shallow processing that makes readers skim, reread infrequently, and pause rarely, which weakens integrative understanding (Clinton, 2019). Second, a calibration gap skews metacognition. Readers overestimate on-screen comprehension and reduce the effort devoted to monitoring and regulation (Liu, Kang, and Song, 2022). Third, hyperlinks, notifications, and multitasking opportunities add extraneous cognitive load that disrupts semantic integration (Diningrat et al., 2023; Khotimah et al., 2024; Mayer, 2014). Targeted supports narrow this gap. Interactive annotation, goal-driven segmentation, and strict control of distractors raise digital comprehension to levels close to print (Baron, 2021; Liu et al., 2022). Evidence now supports a context-sensitive dual-format model. Explicit training in metacognitive and self-regulatory strategies helps readers match format to task complexity, disciplinary norms, and assessment stakes, offering a practical route to consistent comprehension across media in doctoral and undergraduate settings. These findings lead to the cognitive dimension of this issue, where differences in medium use are explained through underlying processes such as attention, working memory, and metacognitive regulation.

Cognitive Differences Between Print and Digital Reading

Text modality impacts reading comprehension and cognitive processing. Print texts generally enhance comprehension compared to digital texts (Clinton, 2019; Delgado et al., 2018; Kong et al., 2018). Digital reading negatively affects comprehension, particularly for informational texts, while narrative texts showed minimal differences between digital and print formats (Clinton, 2019). A consistent advantage for print reading has been found, influenced by reading duration, text genre, and study timing (Delgado et al., 2018). Readers of printed texts performed better in comprehension and recall tasks than digital readers, showing that print supports deeper cognitive processing (Jian, 2022; Kaygısız, 2025). Better comprehension from print without differences in reading speed has been documented (Kong et al., 2018).

Differences in comprehension arise from cognitive demands unique to digital reading, such as scrolling, hyperlink navigation, and distraction management, increasing cognitive load and reducing deep processing (Naumann and Saelzer, 2017; Singer and Alexander, 2017). Print texts encourage linear, focused reading, aided by physical and spatial cues, which improves mental organisation and retention. Readers using print recalled narrative sequences more effectively than digital readers (Mangen et al., 2019). Print-based reading supports deeper comprehension and information retention, especially with complex materials.

These areas are often considered as distinct lines of inquiry despite their overlapping concerns. Limited research has investigated the interaction of academic reading requirements, digital settings, and cognitive processes to drive the achievement of understanding in higher education. Filling this gap enables evidence-based reading instruction that accounts for the realities of digital learning while leveraging cognitive processes that support effective comprehension. The meta-analysis combines the results of these areas to establish coherent patterns and moderating

variables and to provide a holistic picture of when and how print or digital reading is most likely to be effective in supporting learning in university.

RESEARCH METHODOLOGY

This study adopted a systematic review design guided by the PRISMA 2020 statement (Page et al., 2021), which provides a transparent protocol for locating, screening, and synthesising empirical research on digital reading comprehension in higher education. A systematic literature search was conducted across five academic databases: Scopus, Web of Science, ERIC, PsycINFO, and Google Scholar. The first three served as primary sources because of their broad coverage of peer-reviewed research in education, psychology, and learning sciences. PsycINFO was added to capture studies with a strong cognitive or psychological focus. Google Scholar was used to identify additional peer-reviewed articles not indexed in the primary databases.

The search strategy combined three concept blocks: (a) reading medium (digital, screen, online, electronic), (b) the outcome of interest (reading comprehension), and (c) the target population (higher education and undergraduate students). Synonyms and term variants within each concept block were combined with the Boolean operator OR. The three blocks were then combined with AND. Truncation symbols () were used to capture word variants, so that read retrieves read, reading, reader, and readers. Searches were limited to peer-reviewed journal articles published in English between 2017 and 2025.

The search string executed in Scopus was as follows:

TITLE-ABS-KEY ((“digital read*” OR “screen read*” OR “online read*” OR “electronic read*” OR “e-read*”) AND (“reading comprehension” OR “text comprehension” OR “reading performance”) AND (“higher education” OR “universit*” OR “undergraduate*” OR “college student*” OR “tertiary education”)) AND PUBYEAR > 2017 AND PUBYEAR < 2025 AND LANGUAGE (english) AND DOCTYPE (ar)

Equivalent strings were adapted to the syntax of each remaining database, with adjustments made for field tags such as TS= in Web of Science and for the filters supported by each platform.

Eligibility criteria

Studies were deemed eligible when they satisfied all of the following conditions: (a) reading comprehension functioned as the primary dependent variable, (b) participants were matriculated undergraduate or graduate students at accredited postsecondary institutions, (c) the research either compared digital and print modalities or investigated digital reading comprehension in isolation, (d) data collection and analysis followed a quantitative or mixed-methods design, and (e) the article appeared in a peer-reviewed journal published between 2017 and 2025. Studies were excluded when they focused on K–12 populations, failed to report comprehension outcomes, lacked an empirical research design, or did not provide access to the full text.

Each criterion was chosen with a specific methodological purpose. The 2017–2025 publication window was selected to balance temporal relevance with the inclusion of sufficient empirical evidence to support subgroup analysis. The starting point of 2017 marks the period in which tablet and smartphone ownership among university students became near-universal in most high-income contexts, rendering screen-based academic reading a routine rather than an emerging practice (Singer and Alexander, 2017). The endpoint of 2025 ensures that the most recent post-pandemic evidence is captured. This nine-year window spans three pedagogically distinct periods: pre-COVID (2017–2019), during-COVID (2020–2022), and post-COVID (2023–2025). The span directly supports the temporal subgroup analysis specified in the second research question.

The undergraduate and graduate population criterion was applied to address the population gap identified in earlier meta-analyses, which pooled effects across K–12 and adult learners. Restricting

the sample to higher education ensures that the synthesis speaks to instructors and instructional designers working with university-level cognitive demands and disciplinary reading tasks. Reading comprehension was set as the primary dependent variable because studies that measure only adjacent constructs, such as reading speed, eye-movement patterns, or learner attitudes, do not provide a common effect size that can be aggregated meaningfully. The quantitative or mixed-methods design requirement follows directly from this stipulation, as effect size calculation requires reported means, standard deviations, sample sizes, or equivalent statistics. A peer-reviewed journal publication was required to provide a baseline of methodological quality control. The English-language restriction reflects the working language of the review team, and its implications for potential language bias are addressed in the Limitations section.

The inclusion and exclusion parameters were established in accordance with PRISMA guidelines to ensure methodological transparency and reproducibility. A summary of the eligibility standards applied for study selection is presented in Table 1.

Table 1. Eligibility Criteria for Study Selection

Criteria Category	Inclusion Criteria	Exclusion Criteria
Focus Variable	Reading comprehension as the primary dependent variable	Studies not reporting comprehension outcomes
Population	Undergraduate or graduate students in accredited postsecondary institutions	K–12 or non-academic populations
Modality	Comparison of print and digital reading, or digital reading examined independently	Studies unrelated to reading format
Research Design	Quantitative or mixed-methods empirical design	Non-empirical, theoretical, or commentary works
Publication Type	Peer-reviewed journal articles (2017–2025)	Non-peer-reviewed sources, theses, or inaccessible texts
Language	English, full-text available	Non-English or unavailable full-text publications

Search Strategy

A comprehensive literature search was conducted across three primary academic databases: Scopus, Web of Science, and ERIC. Search strings included combinations of keywords such as “digital reading,” “screen reading,” “online reading,” “e-reading,” “reading comprehension,” and “higher education.” Boolean operators (AND, OR) were used to refine results.

Study Selection and Screening

Search records were first imported into Zotero for automatic and manual deduplication. Once duplicate references were removed, two reviewers independently screened titles and abstracts against the predefined inclusion criteria. Inter-rater agreement at this stage was assessed using Cohen's kappa, yielding $\kappa = 0.79$, a value that indicates substantial agreement between reviewers. The same reviewers then evaluated the full texts of all remaining articles, with agreement at the full-text stage reaching $\kappa = 0.86$. Discrepancies at either stage were resolved through discussion, and a third reviewer adjudicated cases that could not be settled through consensus. The study-selection procedure is summarised in the PRISMA flow diagram (Figure 1).

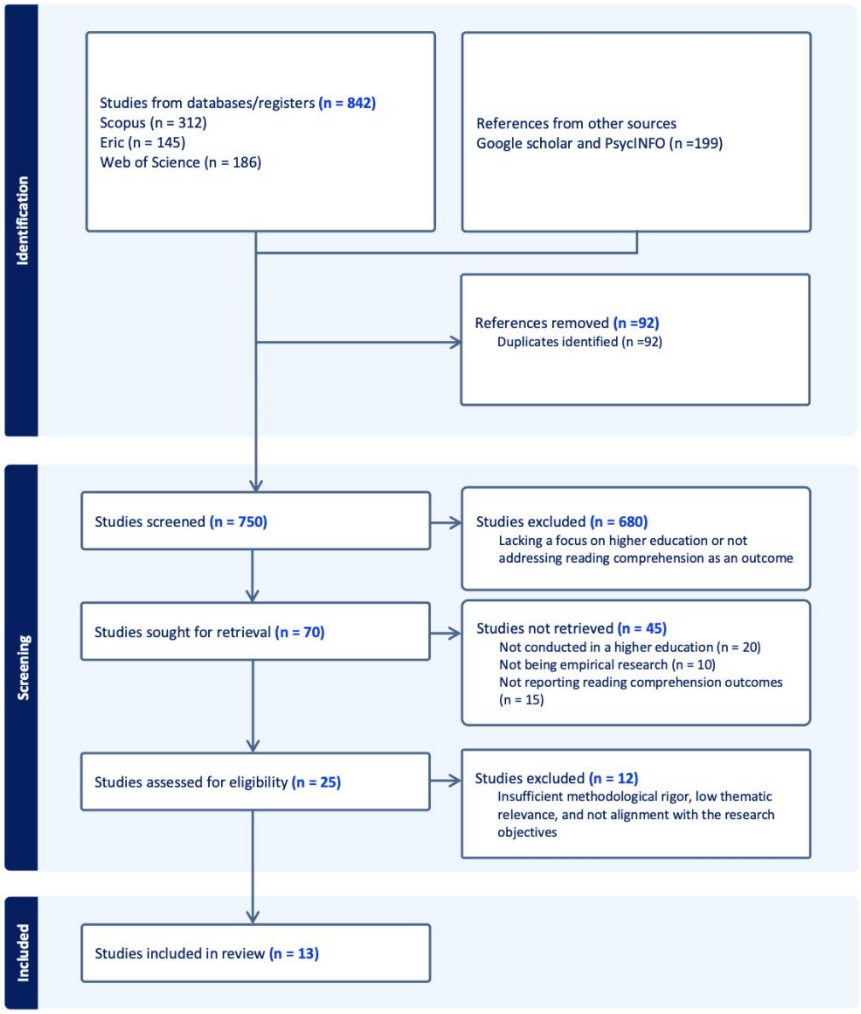

Figure 1. PRISMA Flow Diagram of Screening and Inclusion Process

A comprehensive literature search was conducted across three primary academic databases: Scopus, Web of Science, and ERIC. These databases were selected because of their broad coverage of peer-reviewed research in education, psychology, and learning sciences. To ensure wider retrieval and reduce the risk of missing relevant studies, supplementary searches were conducted using Google Scholar and PsycINFO. Google Scholar was used to identify additional peer-reviewed articles not indexed in the primary databases, while PsycINFO was included to capture studies with a strong cognitive or psychological focus.

During the screening phase, 680 records were excluded due to their lack of focus on higher education or because they did not address reading comprehension as a primary outcome. This left 70 full-text articles for further assessment. Of these, 45 articles were excluded for the following reasons: the study was not conducted in a higher education context (n = 20), was not empirical in nature (n = 10), or did not report reading comprehension outcomes (n = 15).

Subsequently, 25 full-text articles were assessed for eligibility based on methodological rigour, thematic relevance, and alignment with the research objectives. Twelve articles were excluded at this stage due to insufficient methodological quality, limited relevance to the review topic, or lack of alignment with the study's aims. Ultimately, 13 studies met all inclusion criteria and were included in the final systematic review. These studies form the basis of the synthesis and analysis presented in this paper.

Data from each study were extracted using a structured coding sheet developed prior to screening. The sheet captured three categories of information. The first category covered

bibliographic and contextual variables, including author, year, country, language background of participants (L1, L2, or EFL), and pandemic period (pre-, during-, or post-COVID). The second category covered methodological variables, including research design (between-subjects, within-subjects, or counterbalanced), sample size per group, text modality (text-only or multimodal), and the comprehension measure employed.

The third category covered statistical variables required for effect size computation, including means, standard deviations, and sample sizes for digital and print conditions, along with any reported test statistics (t, F, or d) and exact p-values. Two reviewers extracted data independently for the same subset of studies, and discrepancies were resolved through discussion. A descriptive summary of the included studies is presented in Table 2.

Table 2. Summary of Studies Comparing Print and Digital Reading Comprehension

No	Author	Year	Period	Country	Method	Text Modality	Outcome
1	Singer & Alexander (2017)	2017	Pre-COVID	USA	Quantitative, within-subjects design	Text-only	Reading comprehension and prediction accuracy
2	Hermena et al. (2017)	2017	Pre-COVID	UAE	Experimental, controlled display conditions	Text-only	Reading rate, comprehension accuracy
3	Trakhman et al. (2018)	2018	Pre-COVID	USA	Quantitative, within-subjects experimental	Text-only	Reading comprehension and calibration accuracy
4	Sage et al. (2019)	2019	Pre-COVID	USA	Mixed-methods, between-subjects	Text-only	Comprehension quiz, cognitive load, preferences
5	Kazazoglu, (2020)	2020	During-COVID	Turkey	Quantitative, within-subjects experimental	Multimodal	Reading comprehension in EFL context
6	Latini et al. (2020)	2020	During-COVID	Norway & Spain	Eye-tracking experimental study	Multimodal	Integrative processing and comprehension
7	Jeong & and Gweon, (2021)	2021	During-COVID	South Korea	Quantitative, within-subjects experimental	Multimodal	Visual patterns, reading comprehension, and attitudes
8	Delgado & and Salmerón (2022)	2022	Post-COVID	Spain	Experimental, eye-tracking, within-subjects	Text-only	Reading comprehension, metacognitive

No	Author	Year	Period	Country	Method	Text Modality	Outcome
							monitoring, eye-tracking metrics
9	Bresó-Grancha et al. (2022)	2022	Post-COVID	Spain	Experimental, counterbalanced design	Text-only	Reading comprehension and word recognition
10	Jian (2022)	2022	Post-COVID	Taiwan	Experimental, eye-tracking	Multimodal	Reading strategies, eye movement data, comprehension
11	Trakhman et al. (2023)	2023	Post-COVID	USA	Within-subjects design with text modality counterbalancing	Multimodal	Comprehension and calibration from multimodal texts
12	Aziz et al. (2024)	2024	Post-COVID	Pkistan	Quantitative, sequential experimental design	Text-only	Inferential comprehension (analyzing, evaluating, creating)
13	Trakhman et al. (2025)	2025	Post-COVID	USA	Experimental, two-part study (pre-post intervention)	Multimodal	Reading comprehension, calibration accuracy

A review of 13 empirical studies published between 2017 and 2025 reveals distinct trends across three time periods: pre-COVID, during-COVID, and post-COVID. Studies conducted prior to the pandemic (2017–2019) predominantly employed text-only materials and focused on traditional comprehension outcomes such as accuracy, prediction, and cognitive load (Singer & Alexander, 2017; Trakhman et al., 2018). In contrast, research conducted during the COVID-19 pandemic (2020–2021) reflected a marked shift toward multimodal reading environments, incorporating visual elements and digital media to accommodate remote learning settings (Kazazoglu, 2020; Jeong & Gweon, 2021). These studies explored more diverse outcomes, including integrative processing, visual attention, and learner attitudes. Post-pandemic research (2022–2025) reveals a balance between text-only and multimodal approaches, with growing emphasis on advanced methodologies such as eye-tracking and within-subjects experimental designs (Delgado & Salmerón, 2022; Trakhman et al., 2025). Moreover, recent studies extend beyond surface-level comprehension to address metacognitive regulation, reading strategies, and inferential understanding, signalling an evolving research agenda in the digital reading landscape.

Data Analysis Procedures

Hedges' g effect sizes were calculated in Comprehensive Meta-Analysis 4 software using the random-effects model to control for between-study variability between respective 95% confidence intervals and inverse-variance weights. Cochran's Q and I^2 were used to identify heterogeneity across studies, with I^2 interpreted using conventional thresholds of 25%, 50%, and 75%

representing low, moderate, and high heterogeneity, respectively (Higgins et al., 2003). The numerical values are reported in the Results section. Moreover, the subgroup moderator meta-analysis was employed to assess the variance in the effect of the exposure text modality (text-only vs. multimodal) and the pandemic period (pre- vs. during- vs. post-COVID). Funnel plots were created to identify potential publication bias, and Egger's regression test was employed. Additionally, a sensitivity analysis was performed by excluding one study at a time to confirm the study's effect size's stability. All analyses were undertaken following the recommendations established by PRISMA, ensuring the transparency, replicability, and methodological robustness of this meta-analysis.

RESULT AND DISCUSSION

Studies Included in the Systematic Review

Table 3 presents the descriptive statistics extracted from each of the 13 included studies before the synthesised effect size estimates. Reported values include the mean (M), standard deviation (SD), and sample size (N) of reading comprehension scores in the digital and print conditions. These values form the basis on which Hedges' g was computed for each study, and they are reported here in full to allow readers to verify the effect size calculations and to reuse the data in future syntheses.

The specific comprehension measure varies across studies, such as multiple-choice tests, inferential questions, or recall accuracy. Each measure was applied consistently within its own study, which allows within-study comparisons between digital and print conditions to remain valid. Examining these descriptive statistics also offers a preliminary view of the digital-print gap ahead of the formal meta-analytic synthesis presented in the following sections.

Table 3. Descriptive Statistics for Reading Comprehension Scores Across Media.

No	Author	Digital			Print		
		Mean	SD	N	Mean	SD	N
1	Singer & Alexander (2017)	4.72	2.57	90	5.12	2.37	90
2	Hermena et al. (2017)	96.5	7.1	32	96.5	7.1	32
3	Trakhman et al. (2018)	8.88	4.17	57	11	4.64	57
4	Sage et al. (2019)	7.25	2.01	40	7.43	1.57	40
5	Kazazoglu (2020)	68	18.38	30	81.3	16.35	30
6	Latini et al. (2020)	27.96	6.99	50	28.06	6.125	50
7	Jeong & and Gweon (2021)	8.59	0.28	74	8.59	0.22	74
8	Delgado & and Salmerón (2022)	8.33	2.52	58	8.91	2.43	58
9	Bresó-Grancha et al. (2022)	3.45	1.13	40	3.63	1.08	40
10	Jian (2022)	955.78	355.01	26	1090.59	543.5	24
11	Trakhman et al. (2023)	3.07	1.03	54	3.44	0.89	54
12	Aziz et al. (2024)	52.69	16.9	426	58.76	17.14	426
13	Trakhman et al. (2025)	12.26	3.61	70	13.56	3.67	70

Does technology-enhanced reading improve comprehension over print for L1/L2/EFL undergraduates? (RQ1)

This meta-analysis synthesises the findings of 13 primary studies comparing reading comprehension outcomes between digital and print formats using Hedges' g as the standardised

effect size metric. Positive values of Hedges' g indicate a performance advantage favouring print reading, while negative values would favour digital reading.

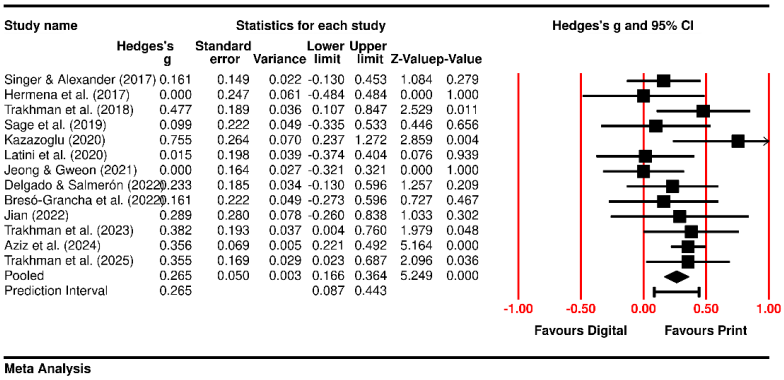

Figure 2. Forest plot of the standardised mean difference in reading-comprehension

As shown in Figure 2, the meta-analysis integrates findings from 13 primary studies that compared reading comprehension outcomes between digital and print formats using Hedges' g as the effect size metric. Positive values of Hedges' g indicate an advantage for print reading, while negative values indicate a benefit for digital formats. The pooled effect size was Hedges' g = 0.265 (SE = 0.050, 95% CI [0.166, 0.364], $p < .001$), suggesting a statistically significant, although small, advantage for print reading comprehension. The prediction interval ([0.087, 0.443]) further supports the robustness of this finding, implying that future studies conducted under similar conditions are also likely to report results favouring print.

Several individual studies contributed significantly to this overall effect, including Trakhman et al. (2018, 2023, 2025), Kazazoglu (2020), and Aziz et al. (2024), which reported medium to large positive effects with statistical significance. In contrast, some studies, such as Hermena et al. (2017) and Jeong and Gweon (2021), reported null effects (g = 0.000, p = 1.000), while others, including Jian (2022) and Sage et al. (2019), showed small and non-significant results. The variation in effect sizes across studies suggests the presence of heterogeneity, which may be attributed to differences in participant demographics, types of reading materials, assessment methods, or the digital platforms used. Although heterogeneity statistics such as the Q statistic and I^2 index were not reported in the figure, the wide confidence intervals observed in some studies imply moderate to substantial variation. Despite this, the overall pattern consistently indicates that print reading tends to be more effective for comprehension than digital reading.

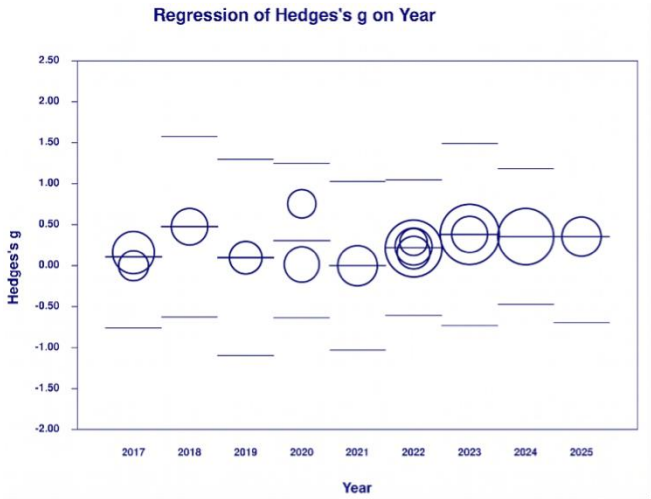

Figure 3. Bubble plot of meta-regression for Hedges's g by publication year

A meta-regression using publication year as a continuous moderator was conducted to examine whether effect sizes shifted over time. The bubble plot in Figure 3 displays a relatively flat

regression line, which indicates no consistent upward or downward trend in Hedges's g across publication years. Individual studies vary in magnitude, ranging from negligible to moderate-to-large effects, yet no temporal pattern is discernible. This stability is consistent with the main meta-analytic finding ($g = 0.265$, $p < .001$) and suggests that the print advantage is not an artefact of evolving technology or publication trends. It reflects persistent cognitive or experiential differences between print and digital reading that have remained largely unchanged over the years covered in this review.

Do digital and print comprehension outcomes differ across pre-, during-, and post-COVID periods for L1/L2/EFL undergraduates? (RQ2)

As the subgroup meta-analysis, depicted in Figure 4, illustrates, the distribution of effect sizes is examined across three temporal categories: Pre-COVID, During-COVID, and Post-COVID. This segmentation enables a more nuanced analysis of whether the relative advantage of print reading over digital formats shifted in response to the educational and technological disruptions brought about by the COVID-19 pandemic. Prior to the pandemic, the pooled effect size was Hedges's $g = 0.206$ ($SE = 0.097$, 95% CI [0.016, 0.396], $p = .034$), indicating a modest but statistically significant advantage for print reading. During the pandemic, the effect size increased slightly to $g = 0.216$; however, this result was not statistically significant (95% CI [−0.204, 0.636], $p = .314$), and the extremely wide prediction interval (−4.551 to 4.983) points to substantial heterogeneity and uncertainty in the findings from that period.

Several factors converge to produce this uncertainty. Only three studies met the inclusion criteria for this period (Kazazoglu, 2020; Latini et al., 2020; Jeong and Gweon, 2021), providing a sparse evidence base on which to construct any subgroup estimate. Within these three studies, the effect sizes were distributed unevenly, with most clustering near zero and one reporting a substantially larger advantage for print, a pattern that produces an unstable between-study variance estimate. Compounding this uncertainty, the studies were conducted in markedly different educational contexts (Turkey, Norway and Spain, and South Korea), each implementing emergency remote learning under different conditions. The During-COVID pooled estimate should therefore be read as descriptive of the included studies rather than as a stable population-level effect.

Two implications follow. The temporal comparison central to the second research question is most defensible between the pre-COVID and post-COVID periods, where the pooled estimates rest on more studies and narrower prediction intervals. Conclusions about how the pandemic itself reshaped digital-print comprehension should remain provisional pending further empirical work.

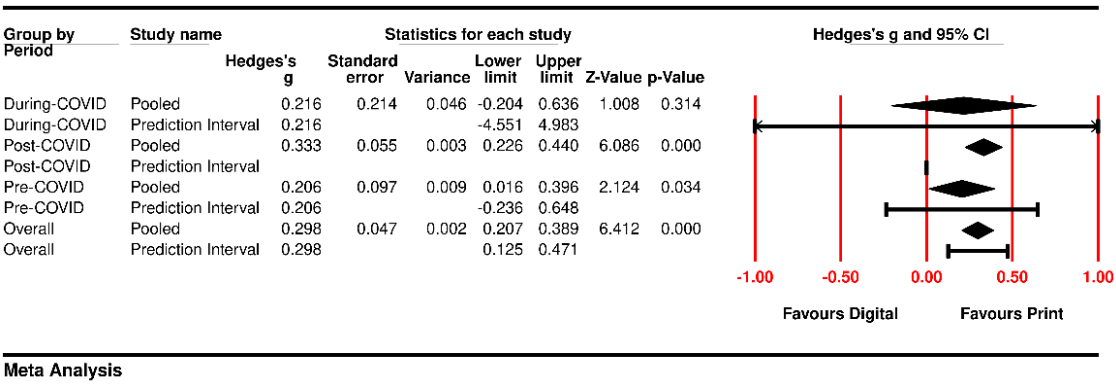

Figure 4. Forest plot of pooled Hedges's g across pandemic periods

In contrast, studies conducted in the post-pandemic period demonstrated a stronger and more consistent effect in favour of print reading, with a pooled Hedges's $g = 0.333$ ($SE = 0.055$, 95% CI [0.226, 0.440], $p < .001$). When data from all time periods are aggregated, the overall effect size

remains statistically significant at g = 0.298 (SE = 0.047, 95% CI [0.207, 0.389], p < .001), reinforcing the overarching pattern that print reading yields superior comprehension outcomes compared to digital formats. These findings indicate that although the advantage of print reading was evident both before and during the pandemic, it became more pronounced in the aftermath. This trend may be attributable to heightened cognitive fatigue resulting from sustained digital engagement, as well as a renewed preference for tangible reading experiences in post-pandemic educational contexts.

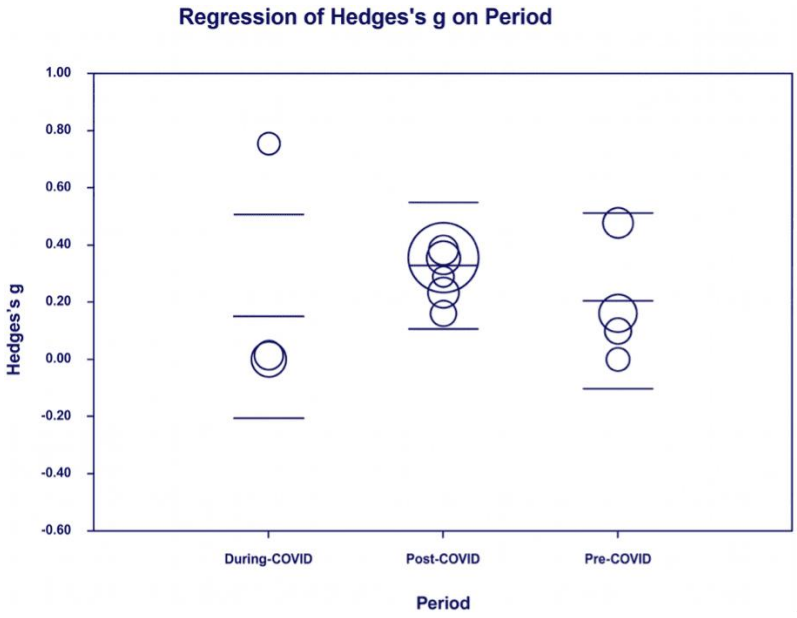

Figure 5. Bubble plot for meta-regression of Hedges's g by pandemic period

Regression of Hedges's g by pandemic period. Post-COVID studies show the most concentrated positive effect sizes, reflecting a stronger and more consistent print advantage. Pre-COVID studies reveal a small, stable effect with slightly wider confidence intervals, while During-COVID studies display the broadest spread, indicative of variability during the rapid transition to digital learning.

Does text modality moderate the digital-print comprehension gap for L1/L2/EFL undergraduates? (RQ3)

The effect of reading format across different types of text modality was examined through a subgroup meta-analysis comparing multimodal and text-only materials, with the results summarised in Figure 6. In the multimodal subgroup, the pooled effect size was Hedges's g = 0.265 (SE = 0.107, 95% CI [0.056, 0.475], p = .013), indicating a small yet statistically significant advantage for print reading. In comparison, the text-only subgroup yielded a slightly larger and more consistent effect size of Hedges's g = 0.291 (SE = 0.052, 95% CI [0.189, 0.393], p < .001), suggesting that the benefits of print are more pronounced when readers engage with purely textual content.

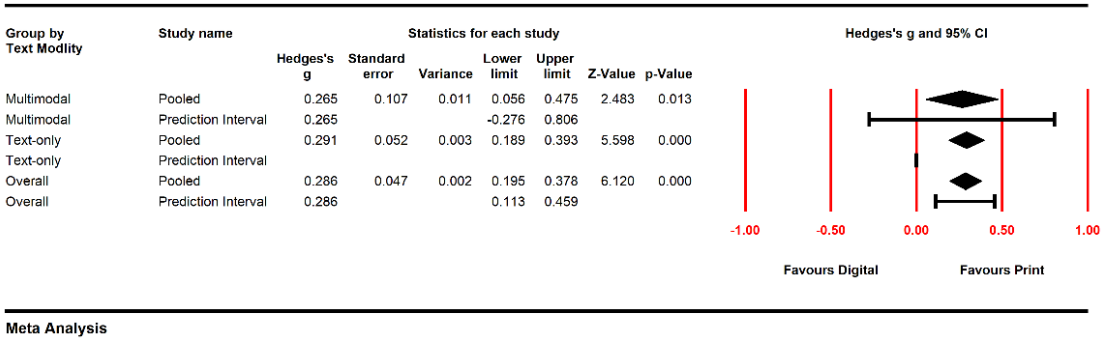

Figure 6. Subgroup forest plot for digital vs print reading comprehension by text modality

Further insights are provided by the prediction intervals. For multimodal texts, the interval ranged from −0.276 to 0.806, encompassing zero and indicating greater variability in effect sizes across studies. This variability implies that comprehension outcomes in multimodal contexts may depend on factors such as content complexity, visual layout, and user familiarity with digital interfaces. By contrast, the prediction interval for text-only materials ranged from 0.113 to 0.459, entirely above zero, suggesting more consistent and reliable advantages for print reading when students are presented with unembellished textual content. This pattern supports the interpretation that print offers greater comprehension benefits, particularly for text-only formats. One possible explanation is that multimodal digital content introduces additional cognitive load, which can disrupt focus and hinder information integration. In contrast, print-based, linear text tends to reduce distractions and facilitate deeper engagement, thereby enhancing comprehension outcomes.

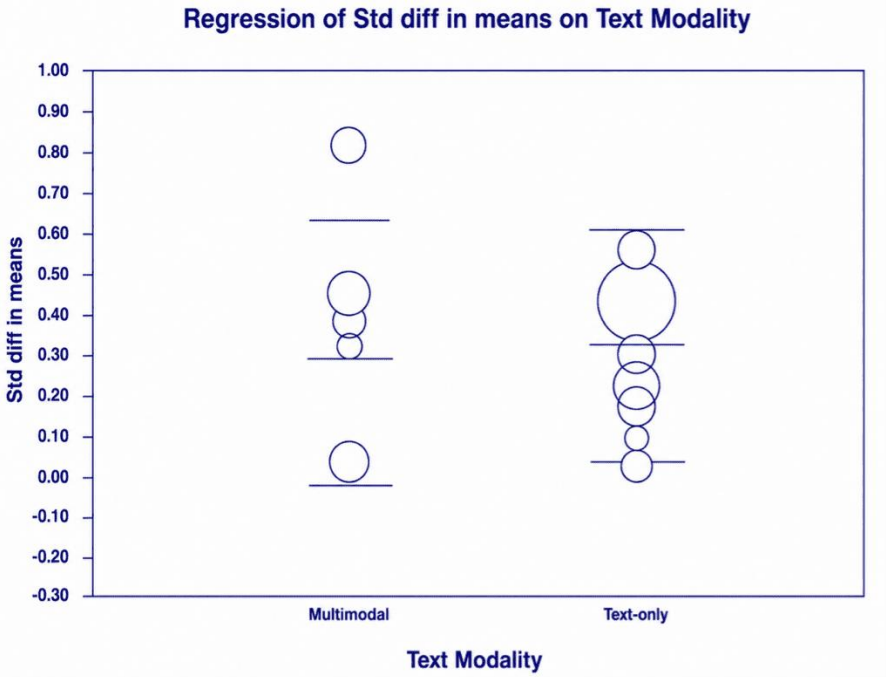

Figure 7. Bubble plot of meta-regression for Hedges's g by text modality

The distribution of standardised mean differences by text modality is visually summarised in Figure 7, which presents the regression analysis of effect sizes grouped by multimodal and text-only conditions. Studies employing text-only materials show a tighter concentration of effect sizes in the moderate positive range, with minimal variability and a strong clustering around the pooled mean. This visual pattern reinforces the earlier finding that text-only reading tasks yield more stable advantages for print. Meanwhile, the multimodal group exhibits a broader spread of effect sizes, ranging from near-zero to moderately high values. This suggests that while print reading may still confer benefits in multimodal contexts, the effects are more heterogeneous, potentially shaped by how visual or interactive elements are designed and integrated into the reading experience.

Publication bias

Figure 8 displays a funnel plot in which the standard error of each study's effect size is plotted against its Hedges's g. The solid vertical line marks the pooled random-effects estimate (≈ –0.28), while the diagonal lines outline the pseudo 95 per cent confidence region expected in the absence of publication bias.

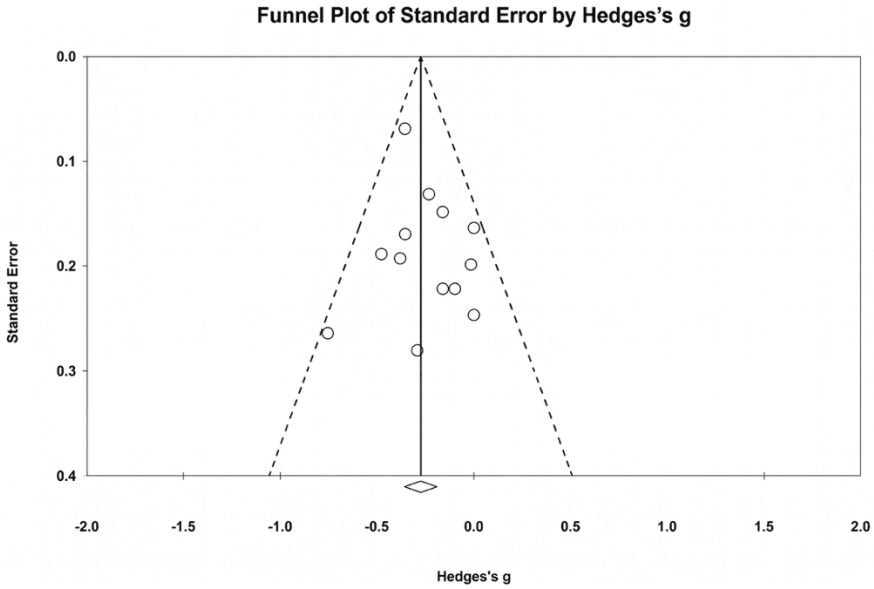

Figure 8. The symmetric funnel plot indicates minimal publication bias.

The funnel plot shows a relatively symmetrical distribution of effect sizes, with precise studies clustered near the top and smaller studies evenly spread below. No evident gap appears in the lower right quadrant, where unpublished pre-print studies would typically accumulate, suggesting the overall estimate is unlikely to be distorted by selective reporting. Statistical tests further support this interpretation. Both Begg and Mazumdar's rank correlation (Kendall's tau = 0.026, p = .903) and Egger's regression intercept test (intercept = 0.608, p = .410) yielded nonsignificant results, confirming that neither small-study effects nor publication bias meaningfully influenced the meta-analytic findings.

Discussion

This meta-analysis examined how reading comprehension differs between digital and traditional print media among undergraduate students in higher education. The limited number of studies meeting the inclusion criteria from 2017 to 2025 reflects the application of rigorous standards. Only studies that provided complete statistical information, employed experimental or quasi-experimental designs featuring both a print control group and a digital experimental group, and focused on postsecondary populations were included.

The meta-analysis revealed a modest yet statistically significant benefit for print formats over digital media, with an overall effect size of Hedges' g = 0.265. This small but consistent advantage was observed across various text genres, with effect sizes of g = 0.291 for text-only materials and g = 0.265 for multimodal materials. These findings suggest that, within contemporary higher education contexts, print reading environments support deeper comprehension than digital reading, especially for cognitively demanding tasks, a pattern consistently reported in prior experimental and meta-analytic research on academic reading (Delgado et al., 2018; Clinton, 2019; de-la-Peña et al., 2024).

In comparison with previous studies, this meta-analysis brings together the already divided evidence and provides a clearer understanding of inconsistencies in the context. Earlier meta-

analyses were based on a general advantage of print but failed to discriminate between groups of learners, text formats, and situations occurring during the pandemic (Clinton, 2019; Delgado et al., 2018; Kong et al., 2018). Other researchers used heterogeneous samples, such as adults and professionals, or did not have strong experimental controls, which restricts the extrapolation to higher education (Flores-Carrasco et al., 2017; Horvath, 2021; Mangen et al., 2019; Schwabe et al., 2021). The current review attempts to fill these gaps by considering only undergraduate students and by implementing uniform inclusion criteria on 13 studies published globally.

This review builds upon the previous research to establish contextual moderators, including pandemic period, type of modality, and complexity of task, that moderate the relationship between reading medium and comprehension. The small yet significant print advantage indicated more extensive involvement with concrete texts before COVID-19 ($g = 0.206$, $p = .034$). The difference was weaker during the pandemic, which is associated with emergency remote learning conditions and increased cognitive stress reported among university students during this period ($g = 0.216$, $p = .314$; Shin et al., 2022; Tabullo et al., 2024). The print benefit resurfaced post-pandemic ($g = 0.333$, $p < .001$), meaning that cognitive differences between media became more subtle as digital infrastructure and instructional design became more developed than they had been.

This research will add value to the literature by incorporating multimodal analyses into understanding the moderating effects of cognitive load and design quality on the outcome of comprehension. Unlike the previous studies where it was assumed that multimedia naturally increased understanding, the current analysis reveals that the ineffective combination of text and images slows down the comprehension process, particularly when multimedia elements increase extraneous cognitive load rather than support integration, as predicted by the Cognitive Theory of Multimedia Learning and confirmed in empirical studies of multimodal reading (Mayer, 2005; Latini et al., 2020; Jian, 2022). Therefore, the success of digital reading is not only related to technology but also to the pedagogical design and metacognitive regulation strategies of students.

Multiple studies investigating reading comprehension among undergraduate populations, including studies conducted in EFL instructional contexts, reported mixed outcomes (Kazazoğlu, 2020; Kaban, 2021; Nguyen, 2023; Pinandito et al., 2021; Luo et al., 2025; Satriani, 2018). Some research found stronger outcomes for print (Kazazoğlu, 2020), while other studies reported higher digital performance (Luo et al., 2025; Satriani, 2018). Methodological differences across these studies complicate comparisons. Some used pre-experimental designs without robust controls, while others failed to report complete statistical data (Flores-Carrasco et al., 2017; Horváth, 2021; Delgado & Salmerón, 2021; Haddock et al., 2020). In some cases, the samples included adults or professionals rather than undergraduates (Mangen et al., 2019; Schwabe et al., 2021).

The current analysis confirmed a consistent benefit for print media across 13 internationally published studies. This aligns with previous findings, all of which found that print enhances reading comprehension more than digital formats (Clinton, 2019; Kong et al., 2018; Delgado et al., 2018). Recent studies also confirm that print supports better cognitive engagement and retention (Adams & Wiley, 2025; Matthews & Johnson, 2023). One study found no difference between formats, highlighting the need to consider contextual factors and task types (Singer & Alexander, 2017).

Meta-analyses have also produced varying effect sizes regarding the medium of reading and comprehension, with several studies suggesting a print advantage (de-la-Peña et al., 2024; Kong et al., 2018; Delgado et al., 2018; Clinton, 2019). In line with these findings, our study conducted a meta-regression analysis revealing an effect size of Hedges' $g = 0.265$, indicating a modest yet consistent advantage for print reading among undergraduate students. This print benefit was observed across various text genres, with effect sizes of $g = 0.291$ for text-only materials and $g =$

0.265 for multimodal materials. While these effects are considered small according to recent benchmarks (Salmerón et al., 2024), they carry meaningful educational implications in the context of evolving digital literacy and the increasing complexity of academic reading. Collectively, these findings suggest that print reading continues to support comprehension more reliably than digital reading, particularly within cognitively demanding higher education environments.

Subgroup analyses revealed that the print advantage shifted across pandemic periods. Before COVID-19, a small but significant benefit for print was observed ($g = 0.206$, $p = .034$), reflecting stronger cognitive engagement with tangible materials. During the pandemic, this advantage weakened and became nonsignificant ($g = 0.216$, $p = .314$), likely due to emergency remote learning transitions, unequal technology access, and heightened cognitive stress that made sustained digital reading more difficult (Tabullo et al., 2024; Shin et al., 2022). Post-pandemic, the print advantage rebounded notably ($g = 0.333$, $p < .001$), driven by improved digital infrastructure, greater familiarity with reading tools, and more intentional instructional design (Chang et al., 2023). Even so, most undergraduates continued to prefer print for deep comprehension tasks, citing eye strain and annotation challenges (Mizrachi & Salaz, 2022). Collectively, these patterns suggest that digital reading success depends less on access alone and more on instructional quality and students' cognitive regulation strategies.

Analysis by text modality revealed that the print advantage was consistent across both text-only and multimodal materials. Both conditions favoured print formats. Text-only studies displayed slightly narrower confidence intervals than multimodal studies, suggesting more precise outcomes ($g = 0.291$ and $g = 0.265$, respectively). The slightly greater variability observed in multimodal reading is attributed to the additional cognitive demands of integrating text and visual information (Latini et al., 2020; Jian, 2022). Eye-tracking research shows that while multimodal materials offer potential benefits by engaging multiple cognitive channels, on-screen readers often underuse visual aids compared to print readers, due to divided attention or surface-level processing (Latini et al., 2020; Jeong & Gweon, 2021). These findings highlight that simply adding multimedia elements does not guarantee improved comprehension. Rather, the quality and integration of multimedia design are crucial. Effective multimodal digital texts should minimise extraneous cognitive load and facilitate meaningful connections between text and visuals to optimise comprehension without overwhelming cognitive resources (Mayer, 2005).

This meta-analysis refines our understanding of medium effects by situating print-digital differences within evolving higher education contexts, offering empirical support for a balanced instructional design in which digital formats expand access and flexibility while print is prioritised for tasks demanding sustained attention and deeper comprehension. The observed print advantage is modest and context-dependent, shaped by learners' cognitive effort, modality design quality, and situational factors such as pandemic-related conditions. Medium effects, therefore, should not be read as deterministic or uniform. They are better understood as emerging from the interaction between reading format and the cognitive and contextual conditions surrounding the reading task.

This synthesis confirms the print advantage already documented at a more general level, and it offers a sharper account of when and for whom that advantage holds. Restricting the analysis to undergraduates shows that the gap reflects features of the academic reading task itself rather than developmental stage, which qualifies interpretations drawn from mixed-age syntheses. The temporal pattern complicates the assumption that prolonged digital exposure would narrow the gap, as the post-pandemic period showed the strongest print advantage in the dataset. The parallel print advantage across text-only and multimodal materials further indicates that added visual elements do not offset the format effect, a pattern consistent with the cognitive theory of multimedia learning

(Mayer, 2005). These observations reposition the field-level discussion from whether digital reading helps or hinders comprehension toward the more productive question of under what conditions each format best supports learning.

The findings also carry implications for theory. One influential account predicts that multimedia enhances comprehension by distributing processing across visual and verbal channels, but only when extraneous cognitive load is minimised. The print advantage observed here for multimodal materials is consistent with this account in its conditional form, since poorly integrated multimedia elements increase extraneous load rather than support meaning construction. The persistence of the print advantage for text-only materials also speaks to arguments about shallow processing in screen-based reading, suggesting that the cognitive costs of digital reading extend beyond multimodal integration to text encoding more broadly. A theoretical implication is the need to distinguish more sharply between the affordances of the medium and those of the instructional design that accompanies it.

CONCLUSION

This meta-analysis synthesised empirical evidence on reading modality among undergraduate students in L1 and L2/EFL settings, reviewing 13 studies published between 2017 and 2025. Results consistently show a small but significant advantage of print over screen reading, particularly for cognitively demanding academic texts requiring deep comprehension, critical thinking, and text synthesis. Digital formats, however, remain beneficial for shorter readings, information searching, and collaborative tasks. Moderating factors such as the pandemic period and text modality confirm that comprehension outcomes are highly context-specific and tied to learners' cognitive and metacognitive processes. Pedagogically, these findings support a blended reading strategy that aligns format with task complexity, integrating digital accessibility with the reflective depth that print reading affords.

DECLARATION OF AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this manuscript, the authors used AI-assisted tools to improve grammar, readability, and clarity of the text. The AI was not used to generate original research content, data, or interpretations. All outputs were reviewed, revised, and validated by the authors. The authors take full responsibility for the accuracy, integrity, and originality of the manuscript.

Example prompt used: “Refine the following academic paragraph to improve clarity, coherence, and grammatical accuracy while preserving the original meaning and content.”

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AUTHORS’ CONTRIBUTION

Author 1: Conceptualization, systematic review design, data extraction, formal analysis (meta-analysis), writing, original draft.
Author 2: Data curation, visualization, writing, review and editing.
Author 3: Investigation, literature review, writing, review and editing.
Author 4: Methodology, validation, statistical review, writing, review and editing.
Author 5: Literature screening, data curation, interpretation of findings, writing, review and editing, supervision.

DECLARATION OF COMPETING INTEREST

The authors declare no financial or non-financial conflicts of interest that could have influenced the design, analysis, or interpretation of the findings.

REFERENCES

Adams, R. L., & Wiley, J. (2025). Impact of prior knowledge and presentation on the place-on-the-page effect. *Discourse Processes, 62*(6–7), 437–456. https://doi.org/10.1080/0163853X.2025.2476326

Ahmed, W. M. A. (2021). Exploring EFL university learners' acquisition of advanced reading skills in the Yemeni context. *Indonesian Journal of Applied Linguistics, 10*(3), 671–680. https://doi.org/10.17509/ijal.v10i3.31765

Anggraini, M. P., Cahyono, B. Y., Anugerahwati, M., & Ivone, F. M. (2022). The interaction effects of reading proficiency and personality types on EFL university students' online reading strategy use. *Education and Information Technologies, 27*(7), 8821–8839. https://doi.org/10.1007/s10639-022-10979-9

Aziz, M., Hassan, A., & Aljamili, O. (2024). The effect of paper reading versus screen reading on the inferential reading performance among university ESL learners. *Jurnal Arbitrer, 11*(1), 85–95. https://doi.org/10.25077/ar.11.1.85-95.2024

Baron, N. S. (2017). Reading in a digital age. *Phi Delta Kappan, 99*(2), 15–20. https://doi.org/10.1177/0031721717734184

Baron, N. S. (2021). *How we read now: Strategic choices for print, screen, and audio*. Oxford University Press.

Bergman, L. (2024). Students' reading in higher education: Challenges and ways forward. *Journal of Adolescent & Adult Literacy, 67*(6), 414–423. https://doi.org/10.1002/jaal.1346

Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2021). *Introduction to meta-analysis* (2nd ed.). Wiley.

Bury, S. (2016). Learning from faculty voices on information literacy: Opportunities and challenges for undergraduate information literacy education. *Reference Services Review, 44*(3), 237–252. https://doi.org/10.1108/RSR-11-2015-0047

Bresó-Grancha, N., Jorques-Infante, M. J., & Moret-Tatay, C. (2022). Reading digital- versus print-easy texts: A study with university students who prefer digital sources. *Psicologia: Reflexão e Crítica, 35*, 10. https://doi.org/10.1186/s41155-022-00212-4

Chang, L., Wang, Y., Liu, J., Feng, Y., & Zhang, X. (2023). Study on factors influencing college students' digital academic reading behavior. *Frontiers in Psychology, 13*, 1007247. https://doi.org/10.3389/fpsyg.2022.1007247

Clinton, V. (2019). Reading from paper compared to screens: A systematic review and meta-analysis. *Journal of Research in Reading, 42*(2), 288–325. https://doi.org/10.1111/1467-9817.12269

Coiro, J. (2021). Toward a multifaceted heuristic of digital reading to inform assessment, research, practice, and policy. *Reading Research Quarterly, 56*(1), 9–31. https://doi.org/10.1002/rrq.302

De-la-Peña, M., Chaves-Yuste, J., & Luque-Rojas, M. J. (2024). Comparing digital and printed reading comprehension in university students: A meta-analytic study. *Journal of Educational Computing Research.* Advance online publication. https://doi.org/10.1177/07356331241237365

de-la-Peña, C., Chaves-Yuste, B., & Luque-Rojas, M. J. (2024). Bridging the printed or digital controversy: A meta-analysis of the impact of digital and print resources on college students' reading comprehension. *Journal of College Reading and Learning, 54*(2), 79–102. https://doi.org/10.1080/10790195.2024.2350949

Delgado, P., Vargas, C., Ackerman, R., Salmerón, L., & Ibáñez-Alfonso, J. A. (2018). Don't throw away your printed books: A meta-analysis on the effects of reading media on reading

comprehension. *Educational Research Review, 25*, 23–38. https://doi.org/10.1016/j.edurev.2018.09.003

Delgado, P., & Salmerón, L. (2022). Cognitive effort in text processing and reading comprehension in print and on tablet: An eye-tracking study. *Discourse Processes, 59*(4), 237–274. https://doi.org/10.1080/0163853X.2022.2030157

Diningrat, S. W. M., Setyosari, P., Ulfa, S., & others. (2023). The effect of an extended flipped classroom model for fully online learning and its interaction with working memory capacity on students' reading comprehension. *Journal of New Approaches in Educational Research, 12*(1), 77–99. https://doi.org/10.7821/naer.2023.1.1073

Dontre, A. J. (2021). The influence of technology on academic distraction: A review. *Human Behavior and Emerging Technologies, 3*(3), 379–390. https://doi.org/10.1002/hbe2.229

Edwards, A. A., Daucourt, M. C., Hart, S. A., & Schatschneider, C. (2023). Measuring reading anxiety in college students. *Reading and Writing, 36*, 1145–1180. https://doi.org/10.1007/s11145-022-10324-z

Grabe, W. (2016). L2 reading comprehension and development. In E. Hinkel (Ed.), *Handbook of research in second language teaching and learning* (Vol. 3, pp. 530–542). Routledge. https://doi.org/10.4324/9781315716893-22

Grabe, W., & Yamashita, J. (2023). Research-based reading instruction. In C. A. Chapelle (Ed.), *The encyclopedia of applied linguistics* (2nd ed.). Wiley-Blackwell. https://doi.org/10.1002/9781405198431.wbeal1174.pub3

Hargreaves, H., Robin, S., & Caldwell, E. (2022). Student perceptions of reading digital texts for university study. *Journal of Learning Development in Higher Education*, (24). https://doi.org/10.47408/jldhe.vi24.817

Hermena, E. W., Sheen, M., AlJassmi, M., AlFalasi, K., AlMatroushi, M., & Jordan, T. R. (2017). Reading rate and comprehension for text presented on tablet and paper: Evidence from Arabic. *Frontiers in Psychology*, *8*, 257. https://doi.org/10.3389/fpsyg.2017.00257

Higgins, J. P. T., Thompson, S. G., Deeks, J. J., & Altman, D. G. (2003). Measuring inconsistency in meta-analyses. *BMJ*, 327(7414), 557–560. https://doi.org/10.1136/bmj.327.7414.557

Holsey Foss, V., Støle, H., & Magyari, L. (2025). The impact of reading medium on text comprehension among vocational students. *Scandinavian Journal of Educational Research,* 1–15. https://doi.org/10.1080/00313831.2025.2506387

Inie, N., Barkhuus, L., & Brabrand, C. (2021). Interacting with academic readings: A comparison of paper and laptop. *Social Sciences & Humanities Open, 4*(1), 100226. https://doi.org/10.1016/j.ssaho.2021.100226

Jeong, Y. J., & Gweon, G. (2021). Advantages of print reading over screen reading: A comparison of visual patterns, reading performance, and reading attitudes across paper, computers, and tablets. *International Journal of Human–Computer Interaction, 37*(17), 1674–1684. https://doi.org/10.1080/10447318.2021.1908668

Jian, Y. C. (2022). Reading in print versus digital media uses different cognitive strategies: Evidence from eye movements during science-text reading. *Reading and Writing, 35*, 1549–1568. https://doi.org/10.1007/s11145-021-10246-2

Kaban, A. (2021). Gamified E-Reading Experiences and Their Impact on Reading *Comprehension* and Attitude in EFL Classes. *International Journal of Mobile and Blended Learning, 13*, 71–90. https://doi.org/10.4018/IJMBL.2021070105

Kaygısız, Ç. (2025). Comparison of digital and printed text reading process. *Education and Information Technologies, 30*(1). https://doi.org/10.1007/s10639-025-13668-5

Kazazoğlu, S. (2020). The impact of digital reading on reading comprehension: A meta-*analysis*. *Journal of Language and Linguistic Studies, 16*(1), 145–163. https://dergipark.org.tr/tr/pub/jlls/issue/53516/712879

Khan, A. U., Ajani, Y. A., & Enakrire, R. T. (2023). From traditional to emerging technologies in *supporting* smart libraries: A bibliometric and thematic approach from 2013 to 2022. *Library Hi Tech, 41*(4), 123–145. https://doi.org/10.1108/LHT-07-2023-0280

Khotimah, K., Basthomi, Y., & Eliyanah, E. (2024). EFL students' self-selected reading in technology-mediated distance learning: A space for learner autonomy. *The Journal of Asia TEFL, 21*(1), 217–226. https://doi.org/10.18823/asiatefl.2024.21.1.14.217

Kong, Y., Seo, Y., & Zhai, L. (2018). Comparison of reading performance on screen and on paper: A meta-analysis. *Computers & Education, 123*, 138–149. https://doi.org/10.1016/j.compedu.2018.05.005

Lavoie, S., Deschênes, M.-F., & Rahimaly, N. (2021). Reading on paper versus screen in health education: A systematic review and meta-analysis. *Medical Education, 55*(10), 1104–1116. https://doi.org/10.1111/medu.14540

Latini, N., Bråten, I., & Salmerón, L. (2020). Does reading medium affect processing and integration of textual and pictorial information? A multimedia eye-tracking study. *Contemporary Educational Psychology, 62*, 101870. https://doi.org/10.1016/j.cedpsych.2020.101870

Li, Y., & Yan, L. (2024). Which reading comprehension is better? A meta-analysis of the effect of paper versus digital reading in recent 20 years. *Telematics and Informatics Reports, 14*, 100142. https://doi.org/10.1016/j.teler.2024.100142

Liu, T. C., Lin, C. C., & Huang, C. W. (2022). Beyond convenience: Investigating the effects of digital reading environments on university students' metacognition and comprehension. *Computers & Education, 186*, 104538. https://doi.org/10.1016/j.compedu.2022.104538

Luo, J., Cao, J., Chan, K., & Yeung, P. S. (2025). Examining the effects of digital academic reading among university students: An integrated framework of three-level digital divide and executive function. *International Journal of Human–Computer Interaction, 1–10*. https://doi.org/10.1080/10447318.2025.2476708

Mayer, R. E. (2001). *Multimedia Learning*. Cambridge University Press.

Mayer, R. E. (2005). *The Cambridge Handbook of Multimedia Learning*. Cambridge University Press.

Mayer, R. E. (2014). Cognitive theory of multimedia learning. In R. E. Mayer (Ed.), T*he Cambridge handbook of multimedia learning* (pp. 43–71). Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.005

Mizrachi, D., & Salaz, A. M. (2022). Reading format attitudes in the time of COVID. *The* Journal *of Academic Librarianship, 48*(6), Article 102598. https://doi.org/10.1016/j.acalib.2022.102598

Nguyen, L. T. (2024). Digital reading of undergraduate students in Vietnamese universities: A focus group study. *Library Management, 45*(1–2), 71–87. https://doi.org/10.1108/LM-06-2023-0052

Ntereke, B. B., & Ramoroka, B. T. (2017). Reading competency of first-year undergraduate students at University of Botswana: A case study. *Reading & Writing, 8*(1), a123. https://doi.org/10.4102/rw.v8i1.123

Orellana, P., Silva, M., & Iglesias, V. (2024). Students' reading comprehension level and reading demands in teacher education programs: The elephant in the room? *Frontiers in* Psychology*, 15*, Article 1324055. https://doi.org/10.3389/fpsyg.2024.1324055

Pedro, L. F. M. G., Barbosa, C. M. M. de O., & Santos, C. M. das N. (2018). A critical review of mobile learning integration in formal educational contexts. *International Journal of Educational Technology in Higher Education, 15*(1). https://doi.org/10.1186/s41239-018-0091-4

Pinandito, A., Hayashi, Y., & Hirashima, T. (2021). Online collaborative Kit-Build concept map: Learning effect and conversation analysis in collaborative learning of English as a foreign language reading comprehension. *IEICE Transactions on Information and Systems, E104.D*(7), 981–991. https://doi.org/10.1587/transinf.2020EDP7245

Salmerón, L., Altamura, L., Delgado, P., Karagiorgi, A., & Vargas, C. (2024). Reading comprehension on handheld devices versus on paper: A narrative review and meta-analysis of

the medium effect and its moderators. *Journal of Educational Psychology, 116*(2), 153–172. https://doi.org/10.1037/edu0000830

Sage, K., Augustine, H., Shand, H., Bakner, K., & Rayne, S. (2019). Reading from print, computer, and tablet: Equivalent learning in the digital age. *Education and Information Technologies, 24*(4), 2477–2502. https://doi.org/10.1007/s10639-019-09887-2

Schwabe, A., Lind, F., Kosch, L., & Boomgaarden, H. G. (2022). No negative effects of reading on screen on comprehension of narrative texts compared to print: A meta-analysis. *Media Psychology, 25*(6), 779–796. https://doi.org/10.1080/15213269.2022.2070216

Segers, E., In 't Zandt, M., Stoep, J., Daniels, L., Roelofs, J., & Gubbels, J. (2022). Differential effects and success stories of distance education in Covid-19 lockdowns on the development of reading comprehension in primary schools. *Reading and Writing, 36*(2), 377–400. https://doi.org/10.1007/s11145-022-10369-0

Singer, L. M., & Alexander, P. A. (2016). Reading across mediums: Effects of reading digital and print texts on comprehension and calibration. *Journal of Experimental Education, 85*(1), 155–172. https://doi.org/10.1080/00220973.2016.1143794

Singer, L. M., & Alexander, P. A. (2017). Reading on Paper and Digitally: What the Past Decades of Empirical Research Reveal. *Review of Educational Research, 87*(6), 1007–1041. https://doi.org/10.3102/0034654317722961

Spitzer, R. L., Kroenke, K., Williams, J. B. W., & Löwe, B. (2021). Does reading anxiety impact on academic achievement in higher education students with dyslexia? *Dyslexia, 27*(3), 263–266. https://doi.org/10.1002/dys.1738

Suhartoyo, E., Afrilyasanti, R., & Mukminatien, N. (2025). Online classroom-based reading assessment: Comprehension and practice development. *Turkish Online Journal of Distance Education, 26*(1), 177–192. https://doi.org/10.17718/tojde.1414226

Tabullo, Á. J., Chiófalo, M. F., & Wainselboim, A. J. (2024). Reading comprehension in undergraduates during the COVID-19 pandemic: Associations with executive function difficulties, reading habits, and screen times. *Reading Psychology, 45*(1), 1–30. https://doi.org/10.1080/02702711.2023.2246972

Talwar, A., Magliano, J. P., Higgs, K., Santuzzi, A., Tonks, S., O'Reilly, T., & Sabatini, J. (2022). Early Academic Success in College: Examining the Contributions of Reading Literacy Skills, Metacognitive Reading Strategies, and Reading Motivation. *Journal of* College *Reading and Learning, 53*(1), 58–87. https://doi.org/10.1080/10790195.2022.2137069

Trakhman, L. M. S., Alexander, P. A., & Silverman, A. B. (2018). Profiling reading in print and digital mediums. *Learning and Instruction, 57*, 5–17. https://doi.org/10.1016/j.learninstruc.2018.04.001

Trakhman, L. M. S., Alexander, P. A., & Fusenig, J. (2025). Reading in print and digitally: Profiling and intervening in undergraduates' multimodal text processing, comprehension, and calibration. *Learning and Individual Differences, 118*, 102627. https://doi.org/10.1016/j.lindif.2025.102627

Trakhman, L. M. S., Alexander, P. A., & Sun, Y. (2022). The effects of processing multimodal texts in print and digitally on comprehension and calibration. *The Journal of Experimental Education, 91*(4), 599–620. https://doi.org/10.1080/00220973.2022.2092831

Yulia, M. F., Sulistyo, G. H., & Cahyono, B. Y. (2020). Affective engagement in academic reading: What EFL student teachers reveal. *International Journal of Evaluation and Research in Education, 9*(3), 791–798. https://eric.ed.gov/?id=EJ1274719