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61

62 **Abstract**

63 **Objective:** To evaluate the effect of digital-based reading versus paper-based reading on reading
64 comprehension among students, trainees, and residents participating in health professional education.

65 **Introduction:** Several reviews have examined the effects of reading media on reading comprehension;
66 however, none have considered health professional education specifically. The growing use of electronic
67 media in health professional education, as well as recent data on the consequences of digital-based reading
68 on learning, justify the necessity to review the current literature to provide research and educational
69 recommendations.

70 **Inclusion criteria:** Studies conducted with health professions students, trainees, and residents
71 individually receiving educational material written in their first language in a paper-based or a digital-
72 based format will be considered. Studies conducted among participants with cognitive impairment or
73 reading difficulties will be excluded. Observational, experimental and quasi-experimental studies that
74 assess reading comprehension measured by previously validated or researcher-generated tests will be
75 considered.

76 **Methods:** Relevant studies will be sought from CINAHL, Embase, ERIC, Google Scholar, MEDLINE,
77 PsycINFO, and Web of Science (SCI and SSCI), without date or language restrictions. Two independent
78 reviewers will perform title and abstract screening, full-text review, critical appraisal, and data extraction.
79 Disagreements will be resolved through discussion or with a third independent reviewer. Synthesis will
80 occur at four levels (i.e., study, participant, intervention, and outcome levels) in a table format. Data will
81 be synthesized descriptively and with meta-analyses if appropriate.

82 **Systematic review registration number:** CRD42020154519.

83 **Keywords:** Books; health professional education; systematic review; reading comprehension; reading
84 media

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88 Introduction

89 A current and growing trend in undergraduate, graduate, and postgraduate health professional education
90 (HPE) is the shift from paper-based learning materials to various types of digital media, such as
91 computers, smartphones, or tablets. Studies investigating the impact of media on learning outcomes have
92 yielded inconsistent findings.^(1, 2) These inconsistencies may be explained by overlooked factors such as
93 task characteristics (e.g., content, duration), participant characteristics (e.g., technological literacy),
94 display technology (e.g., color screen versus black-and-white screen), and electronic features (e.g.,
95 animations, hyperlinks). These factors may act as confounding variables in the assessment of reading-
96 related learning processes.⁽³⁾

97 Reading comprehension is the capacity to appraise, evaluate, integrate, and remember information.⁽⁴⁾ A
98 recent meta-analysis on the effects of reading media on reading comprehension suggested an advantage
99 of paper-based over digital-based reading when considering three moderators: time frame, text genre,
100 and publication year.⁽³⁾ The advantages of paper-based over digital-based reading were observed in time-
101 constrained settings and across text genres (i.e., in studies using informational text only, or a mix of
102 informational and narrative texts), and tended to increase in recent studies. Thus, paper-based reading
103 would be preferable for the comprehension and long-term retention of information contained in a text.⁽³⁾
104 The use of digital media could lead to decreased understanding of the texts and retention of information,
105 especially when texts are long or reading is time-constrained. These effects would be independent of the
106 reader's age. In the long term, this could eventually impact learners' ability to critique, integrate, and
107 evaluate the information they read – a fundamental element to HPE.⁽⁴⁾

108 Paper-based reading may be more effective for several reasons. First, it is suggested that digital-based
109 reading leads to overconfidence in one's perceived acquisition of knowledge, which may ultimately result
110 in diminished understanding or integration.⁽⁵⁾ Second, emerging data indicates that reading with digital
111 media may lead to more surface reading,⁽⁶⁾ which in turn impairs learning.⁽⁵⁾ Digital media are frequently
112 used for rapid everyday tasks (e.g., social media), which may partially explain the tendencies for shallow
113 reading. Third, it is believed that learners' variable experience with technology acts as a moderator in the
114 effect of digital-based reading on comprehension.⁽⁷⁾ Even if students prefer digital media, this does not
115 necessarily result in increased reading comprehension.⁽⁴⁾ Finally, paper-based documents provide a
116 physical "presence" to the text, which would facilitate learning.^(1, 3, 4) This feeling of physical presence
117 could be associated with, for example, knowing that a particular sentence or concept is at the bottom of a
118 particular page in a printed text.^(1, 4) However, no substantial data exist to back up these potential
119 explanations.

120 While previous reviews have been conducted to assess the impact of reading media on reading
121 comprehension,^(1, 2, 3, 4, 8, 9) none has focused specifically on HPE. This is problematic, since reading
122 comprehension has unique implications in the context of HPE. First, reading comprehension in the

123 context of HPE is clinically relevant. Sub-optimal reading comprehension in HPE, if not properly
124 addressed, may lead to increased misconceptions, faulty decision-making, and a consequent increase in
125 medical errors.^(10, 11) Second, previous reviews have focused on heterogeneous populations. For
126 instance, Delgado et al. conducted a systematic review that included a heterogeneous population across
127 the following educational levels: elementary, middle or high school, undergraduates, or graduates and
128 professionals. However, due to the small number of studies with sufficient data to calculate effect sizes,
129 the category “graduates or professionals” was omitted from the analysis. In addition, while the between-
130 group effects were non-significant, none of the comparisons were relevant for this population of interest
131 (i.e., health professional students, trainees, and residents). Third, although previous reviews investigated
132 the impact of text genre (i.e., informational, narrative, or mixed) on reading comprehension, they did not
133 investigate the differences in effects of *theoretical* texts and *applied* texts (i.e., texts that contain
134 information that will be applied in clinical practice) on reading comprehension. Finally, the quantity of
135 medical knowledge to assimilate in order to graduate from a HPE program is growing exponentially.
136 Medical knowledge was estimated to double every 3.5 years in 2010 and every 0.2 years (i.e., 73 days) in
137 2020.⁽¹²⁾ Because knowledge is expanding faster than students’ ability to assimilate it, it is essential to
138 ensure optimal comprehension, integration, and retention.

139 Some studies assessed the impact of reading media on reading comprehension in HPE. Notably, two
140 studies conducted in this context found no difference in the impact of digital-based versus paper-based
141 reading on comprehension.^(13, 14) In these two studies, there were differences in terms of reading time
142 frame (free versus limited) and text genre (information versus narrative). No strategies were used to
143 enhance reading comprehension (e.g., highlighting, note taking). Thus, it would be relevant to investigate
144 the impact of these variations on reading comprehension in the context of this review.

145 A search of PROSPERO, MEDLINE, the Cochrane Database of Systematic Reviews and *JBI Evidence*
146 *Synthesis* was conducted and no published or ongoing systematic reviews on the effects of reading
147 media in HPE were identified.

148 **Review question**

149 Among students, trainees, and residents participating in HPE, what is the effect of digital-based reading
150 versus paper-based reading on reading comprehension?

151 **Inclusion criteria**

152 **Participants**

153 This review will include studies conducted with undergraduate and graduate students of any age, in any
154 health care context and from any discipline who participate in health professional education (i.e.,

155 undergraduate or graduate courses or programs for healthcare professionals). We will also include trainees
156 and residents in medicine and other disciplines (i.e., individuals undertaking postgraduate training). Studies
157 with individuals that have reading difficulties, cognitive impairments, and other related disorders (e.g.,
158 attention deficit hyperactivity disorder) will be excluded.

159 **Intervention**

160 Studies that evaluate the effect of paper-based reading will be included. Paper-based reading is defined as
161 reading texts printed on paper (e.g., printed books, printed articles).⁽³⁾ Studies assessing the impact of texts
162 with wide-ranging characteristics (e.g., informational, narrative, linear, non-linear) will be included.⁽¹⁵⁾ If
163 students were allowed to print the digital text, the study will be excluded from the review.

164 **Comparator**

165 Studies that compare the effects of paper-based reading directly to that of digital-based reading will be
166 included. Studies that do not include a comparator will be excluded from the review. Digital-based reading
167 is defined as “reading texts on digital screens, including computers, tablets, mobile phones, and e-
168 readers.”⁽³⁾ It is important that the reading materials evaluated in studies are comparable across media
169 (i.e., similar content, structure, and images); thus, studies will be excluded if the digital-based condition
170 includes features such as videos, animations, hyperlinks,⁽¹⁶⁾ web navigation,⁽¹⁷⁾ gamification,⁽¹⁸⁾ and
171 adaptivity.⁽¹⁹⁾

172 **Outcomes**

173 The primary outcome of this review is reading comprehension (i.e., the understanding of the textual
174 content in paper or digital formats). More specifically, this review will consider studies reporting outcomes
175 related to textual, inferential, and mixed types of reading comprehension. Textual reading comprehension
176 is associated with reading tasks that ask “for specific details or shallow level of comprehension”.⁽³⁾
177 Inferential reading comprehension is equivalent to high-level comprehension, when reading tasks require
178 “inferences based on parts of the texts, across parts, or involved previous knowledge”.⁽³⁾ Mixed reading
179 comprehension is associated with reading tasks that require both types of reading comprehension.⁽³⁾ This
180 review will consider all methods to assess reading comprehension, regardless of prior psychometric
181 evaluation.

182 In addition, variables that could influence the relationship between interventions and outcomes, such as
183 learners’ self-reported experience with using technology and preference for paper-based or digital-based
184 reading, will be extracted and reported. We will consider subjective measures of learners’ experience and
185 preference (i.e., Likert-type questionnaires).

186 **Types of studies**

187 This review will comprise observational, quasi-experimental, and experimental study designs including

188 randomized controlled trials, non-randomized controlled trials, before and after studies, case-control
189 studies, interrupted time-series studies, and cohort studies. This review will consider studies published in
190 any language in peer-reviewed journals or peer-reviewed conference proceedings. This review will
191 exclude qualitative studies, discussion papers, editorials, knowledge syntheses, dissertations, and
192 theses.

193 **Methods**

194 The proposed systematic review will be conducted in accordance with JBI methodology for systematic
195 reviews of effectiveness evidence⁽²⁰⁾ and the Preferred Reporting Items for Systematic review and Meta-
196 Analysis Protocols (PRISMA-P) checklist.⁽²¹⁾ The methods described in this systematic review protocol
197 were piloted by review authors in previous reviews.^(18, 22, 23) The title of this review was registered in the
198 JBI Registry on October 13, 2019. This protocol is pending registration in PROSPERO (ID15451).

199 **Search strategy**

200 An initial limited search of MEDLINE was undertaken in August 2019 to identify relevant articles on the
201 topic. The authors worked in collaboration with an experienced librarian to refine the search strategy to
202 ensure specificity, sensibility, and replicability in all databases. The search strategy is based on a
203 combination of three concepts: (1) students, trainees, and residents participating in HPE (population); (2)
204 reading media (intervention); and (3) reading comprehension (outcome). The search strategy was first
205 developed for MEDLINE (Appendix I), and then tailored to each bibliographical database.

206 **Information sources**

207 Systematic searches will be performed in six bibliographical databases: CINAHL (EBSCOhost; 1980 to
208 present); Embase (Ovid SP; 1974 to present); ERIC (ProQuest; 1966 to present); MEDLINE (Ovid SP;
209 1946 to present); PsycINFO (EBSCOhost; 1967 to present); Web of Science – Science Citation Index (SCI)
210 Expanded and Social Sciences Citation Index (SSCI; Clarivate Analytics; 1900 to present).

211 In addition to the search in bibliographical databases, reference lists of included studies will be manually
212 screened to identify additional studies. Relevant journals (e.g., MedEdPORTAL) will be searched for
213 additional studies, as will Google Scholar for related systematic reviews.

214 **Study selection**

215 All identified citations will be uploaded into EndNote X9.2 (Clarivate Analytics, PA, USA) and duplicates
216 removed. Titles and abstracts will be screened by two independent reviewers for assessment against the
217 inclusion criteria. Potentially relevant studies will be retrieved in full and their citation details imported into
218 the JBI System for the Unified Management, Assessment and Review of Information (JBI SUMARI; JBI,
219 Adelaide, Australia). The full text of selected citations will be assessed in detail against the inclusion

220 criteria by two independent reviewers. Reasons for the exclusion of full-text studies that do not meet the
221 inclusion criteria will be recorded and reported in the systematic review. At any time during the review
222 process, disagreements will be resolved through discussion and consensus or via a third reviewer. The
223 study selection process will be reported in a Preferred Reporting Items for Systematic Reviews and Meta-
224 Analyses (PRISMA) study flow diagram.⁽²¹⁾

225 **Assessment of methodological quality**

226 All included studies will be critically assessed by two independent reviewers. The standardized critical
227 appraisal tools incorporated within JBI SUMARI will be used to assess the risk of bias of experimental,
228 quasi-experimental studies, and observational studies.⁽²⁷⁾ For experimental studies, reviewers will score a
229 total of 13 criteria as being met (yes), not met (no), unclear or, where appropriate, not applicable (n/a) to
230 that particular study. For quasi-experimental studies, reviewers will score a total of nine criteria using the
231 same response scale. For observational studies (e.g., cohort studies), reviewers will select the
232 appropriate checklist for each study design in the JBI Reviewer's Manual.⁽²⁷⁾ Any disagreements that arise
233 between the reviewers during the assessment of methodological quality will be resolved through
234 discussion, or with a third reviewer. Where there is missing data or a need for clarification, authors of
235 papers will be contacted.

236 Studies will not be excluded on the grounds of their risk of bias, but the risk of bias will be reported when
237 presenting the results. The risk of bias judgments will be summarized across different studies for each of
238 the domains listed using the risk of bias graph and the risk of bias summary.

239 **Data extraction**

240 Data will be extracted independently by two reviewers from included studies using the standardized JBI
241 data extraction tool.⁽²⁰⁾ Any disagreements arising during this phase of the review will be resolved through
242 discussion, or with a third reviewer. In cases where there is missing data or a need for clarification,
243 authors of papers will be contacted. Data will be collected at the following levels:

- 244 • Study level: study design, year of study, sample size, type of randomization, setting, country of
245 study conduct, and corresponding author's contact information;
- 246 • Participant level: type and number of participants, eligibility criteria, withdrawals and exclusions
247 (loss to follow-up), age, sex, level of instruction, practice setting, self-reported experience with using
248 technology, self-reported preference for paper-based or digital-based reading;
- 249 • Intervention level: clinical topic (e.g., pharmacology), text length (i.e., number of words and number
250 of pages; text will be categorized as either short [< 1000 words] or long [≥ 1000 words]),⁽³⁾ allowed
251 reading time frame (i.e., free or limited), type of paper-based media (e.g., printed book, printed
252 article) or type of digital device (e.g., computer, laptop, smartphone), text genre (i.e., information,

- 253 narrative, or mixed),⁽³⁾ need for scrolling (i.e., yes or no), strategies used to enhance reading
254 comprehension (e.g., use of highlighting, note taking);
- 255 • Outcome level: name, time points measured, definition, unit of measurement, scales, validation of
256 measurement tool, results.

257 **Data synthesis**

258 Characteristics of included studies will be synthesized at four levels (i.e., study level, participant level,
259 intervention level, outcome level) in table format. For observational studies, results will be presented
260 descriptively.

261 For quasi-experimental and experimental studies, as clinical and methodological diversity is anticipated,
262 all summary intervention effects estimates will be presented using a random effects model. Data for
263 continuous outcomes will be analyzed using standardized mean differences with 95% confidence
264 intervals. It is not expected that studies will have the same outcome measures/scales. Data for
265 dichotomous outcomes will be analyzed using risk ratios and 95% confidence intervals. Each paired
266 comparison relevant to this review will be included separately for studies with multiple intervention
267 groups; however, shared intervention groups will be divided among the comparisons.⁽²⁸⁾

268 Meta-analyses will be undertaken to compare the effects of reading media on reading comprehension if: i)
269 the interventions and the research questions are similar enough for pooling to make sense; and ii) there
270 are at least two studies available for each outcome of interest. Meta-analyses will be conducted in Review
271 Manager (RevMan) v5.3 (Copenhagen: The Nordic Cochrane Centre, Cochrane). A narrative summary of
272 the results will be presented if it is not possible to conduct a meta-analysis.

273 Heterogeneity will be first assessed by examining the characteristics of included studies, the similarities
274 and disparities between participants, interventions, and outcomes. Heterogeneity will then be assessed
275 statistically using standard chi-square and I^2 tests within RevMan. A statistical significance level (P value)
276 of 0.10 will be used for the chi-square statistic instead of the conventional level of 0.05, as this test is
277 known to have low statistical power.²⁴

278 Subgroup analyses will be carried out to investigate heterogeneity when two or more studies are available
279 in the underlying outcome. The following potential effect modifiers will be explored: type of paper-based
280 or digital-based reading media; clinical topic of reading; discipline of health professional students; and
281 study design.

282 If there are 10 or more studies included in the meta-analysis for the primary outcome (i.e., reading
283 comprehension), a funnel plot will be generated using RevMan to assess publication bias; an
284 asymmetrical funnel plot will be indicative of publication bias. If appropriate, to further assess publication
285 bias, Egger's regression will be performed using IBM SPSS Statistics version 25 (Armonk, NY: IBM

286 Corp).²⁵ A *P* value \leq to 0.05 for the constant of the regression will be indicative of publication bias.

287 **Assessing certainty in the findings**

288 A Summary of Findings will be created for the main intervention comparisons and will include the most
289 important outcomes (e.g., reading comprehension) to draw conclusions about the certainty of the
290 evidence. The quality of the evidence will be assessed independently for each outcome according to the
291 five domains (risk of bias, inconsistency, indirectness, imprecision, and publication bias) established by
292 the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) guidelines.²⁶
293 Review authors will use GRADEpro (McMaster University, ON, Canada), based upon extracted data.

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303 **Conflicts of interest**

304 ML has received speaker fees from Bayer; has participated in industry-funded trials from Idorsia; and has
305 received in-kind and financial support for investigator-initiated grants from Leo Pharma, Roche
306 Diagnostics and AggreDyne for unrelated work. SdeD was supported through grants from Pfizer,
307 AstraZeneca, Roche Molecular Science, and DalCor for unrelated work. PL has provided consultant
308 advice to Chenelière Éducation for textbook translation and adaptation.

309 The other authors declare no conflict of interest.

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392

393 **Appendix I – MEDLINE search strategy**

394

Concepts	#	Searches	Results (April 16, 2020)
A	1	((Health or Medical or Emergency or Radiotherapy or Cardiology or Cardiac or Surgical or Respiratory therapy or Radiology or Physiotherapy or Psychiatry or Psychology or Psychotherapy or Anesthesiology or Audiology or Chiropractic or Dental or Dermatology or Dietetic? or Nutrition* or Endocrinology or Gastroenterology or Gynecology or Nursing or Optometry or Occupational therapy or Pathology or Paramedic? or P?ediatric or Pharmacy or Pharmacology or Physician? or Podiatry) adj2 (Student? or Trainee? or Intern?)).tw.	77,994
A	2	(Residen? or clinical clerkship?).tw.	65,838
A	3	exp education, graduate/ or clinical clerkship/ or education, medical, undergraduate/ or exp teaching rounds/ or Education, Nursing, Associate/ or Education, Nursing, Baccalaureate/ or Education, Nursing, Diploma Programs/ or Nursing Education Research/ or Pharmacy Residencies/ or exp Students, Health Occupations/ or Education, Predental/ or Education, Premedical/	176,931
	4	1 or 2 or 3	260,209
B1	5	((Book? or Textbook? or Print* or Paper or Physical media) adj1 read*) or bookread*).tw.	750
B1	6	exp Textbooks as Topic/	2,285
B2	7	((Computer* or Laptop? or Smartphone? or Electronic book? or Ebook? or E-book? or Kindle or Online or on-line or Blended learning or Web* or Learning management system? Or LMS or Moodle or E-learning or Elearning or Digital or eReader? Or Screen or Learning environment? or virtual) adj1 read*).tw.	971
B2	8	exp Education, Distance/	3,885
B3	9	((((media or medium or media) adj (effect? or platform*)) or Chapter? or Article? or text-based or textbased or Mode of presentation or Presentation mode?) adj1 read*).tw.	314
	10	5 or 6 or 7 or 8 or 9	8,150
C	11	(knowledge or memory or comprehension or recall or retention or test* or learning).tw.	4,145,079
C	12	exp academic performance/ or exp comprehension/ or exp memory/	148,605
	13	11 or 12	4,176,649
	14	4 and 10 and 13	1,177