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Does Reading while Listening to Text Improve Comprehension Compared to Reading Only? A Systematic Review and Meta-Analysis

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Abstract: *Due to technological advancements such as text-to-speech software, reading while listening (audio-assisted reading) is widely available. However, the findings are mixed on the effectiveness of reading while listening as a tool to improve comprehension. The purpose of this study is to synthesize existing studies on reading while listening to determine for whom and under what circumstances reading while listening is helpful. A systematic review with a meta-analysis was conducted in which 30 eligible studies (total N = 1945) with 62 effect sizes were examined. Using robust variance analysis, a trivial overall benefit of reading while listening over reading only on comprehension was found g = .18, SE = .07, p = .01. Based on a meta-regression, this benefit appeared to be limited to studies in which reading was paced by the experimenter, g = 0.41, SE = 0.12, 95% CI = [0.13, 0.70], p = .01. There were no reliable effects of reading while listening when reading was self-paced, g = 0.06, SE = 0.06, 95% CI = [-0.07, 0.19], p = .34. Struggling readers' overall comprehension and second language learners' incidental vocabulary acquisition may be benefited through audio-assisted reading, but there are currently too few studies to afford generalizations on these claims.*

Keywords: audio-assisted reading, meta-analysis, reading while listening, reading comprehension, systematic review

Reading while listening to a text, also known as audio-assisted reading, has been documented as an effective accommodation to assist students with reading disabilities with comprehension (Wood et al., 2018). Audio features such as text to speech are also more commonly available with the increasing popularity and accessibility of electronic books (Fichten et al., 2022; Yesberg, 2022). However, it is unclear what the effects of reading while listening to the text

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compared to reading alone are for groups of readers other than those with reading disabilities. Previous studies have had mixed findings with some indicating an advantage of reading while listening (e.g., Keelor et al., 2018, 2020; Teng, 2018), some an advantage of reading alone (Holmes, 1985; Holmes & Allison, 1986), and some indicating no difference (Kopp & D'Mello, 2016; Taake, 2009). Due to these mixed findings, a comprehensive synthesis needs to be conducted to understand whether adding audio of text while reading is advisable for whom under what circumstances. Such a synthesis would indicate the overall effect of reading while listening as well as discern how the effects vary depending on the reader, text, and situational circumstances. The purpose of this study is to conduct a systematic review and meta-analysis comparing reading while listening to reading only on comprehension.

Theoretical Frameworks

Many readers can adequately decode but have difficulty understanding what they read resulting in poor reading comprehension (Barth et al., 2015; Spencer & Wagner, 2018). This issue is explained by the *simple view of reading* (SVR) in which reading comprehension is the product of decoding and language comprehension skills (Hoover & Gough, 1990). SVR has been supported by numerous studies indicating a substantial proportion of individual differences in reading comprehension skill can be explained by the product of decoding and language comprehension skills (see Catts, 2015, for a review). If a reader struggles with decoding, then listening to the text while reading would likely assist them in understanding the text if they have adequate aural comprehension skills (Chang & Millett, 2015; Reitsma, 1988).

Specifically describing comprehension independent of decoding, the *construction-integration model* provides a framework of the process of comprehension (Kintsch, 1988). During construction, readers activate knowledge relevant to the text, which is integrated in a dynamic process during reading (Kintsch, 1998). A key assumption of the construction-integration model is that there are three levels of representation of text: the surface structure, the textbase, and the situation model. The surface structure is the literal words and syntax of the text. The textbase is composed of the ideas of the text, known as propositions, which are connected in a coherent manner. Readers integrate relevant background knowledge with the textbase to develop a situation model. Inferences, in which the reader connects ideas within the text or between the text and background knowledge, are necessary for successful textbase and situation models (Kendeou, 2015). As the reader encounters new ideas, the situation model is updated to accommodate them.

Because of the complexities involved in constructing these three levels of representation and coordinating them, reading comprehension requires substantial information processing skills, particularly in terms of working memory capacity (Kim, 2017). There are competing theoretical frameworks based on working memory capacity regarding the effects of comprehension when listening to a text while reading it. One is the dual channel assumption in which there are separate channels for visual and auditory information to be processed in working memory (also referred to as the separate streams hypothesis; Penney, 1989). Because there are separate channels, it follows that more information can be processed if both channels are used (Lee & Mayer, 2018; Mayer & Moreno, 2003). Based on this assumption, reading while listening to text would yield better comprehension than reading alone since the text would be processed through two channels. Conversely, cognitive load theory, is based on the assumption that humans have limited cognitive resources for processing information (Baddeley, 1999; Sweller, 2011). Presenting the same information (such as the verbal information in text) in two different modalities (written and audio) would be duplicative and overload limited working memory resources (redundancy effect;

Sweller, 2020). This exhaustion of working memory would make it more difficult for readers to comprehend the text thereby yielding poorer comprehension when reading while listening compared to reading alone.

Potential moderators

Generally, reading is done at one's own pace and listening is at the pace of the speaker. Following this, reading while listening studies often have reading-while-listening conditions at a pace determined by the experimenter (experimenter paced) and reading conditions at a pace determined by the participant (self-paced). However, some studies have self-pacing for reading while listening that allows for re-reading and re-listening to text (e.g., Conklin et al., 2020). Moreover, some experimenters controlled the pacing in the reading-only condition to have it more similar to the reading-while-listening condition (e.g., Alvarez-Alonso et al., 2021; Chen, 2021). In a previous meta-analysis comparing reading to listening comprehension, pacing was an important moderator (Clinton-Lisell, 2022). When reading was self-paced and listening was experimenter-paced, reading yielded better comprehension than listening. In contrast, when reading and listening were both experimenter-paced, reading and listening were not reliably different (note that there were no studies included in the Clinton-Lisell, 2022, meta-analysis in which listening could be self-paced). Therefore, pacing may be a critical factor when considering differences in comprehension between reading while listening and reading alone.

Similar to pacing is the issue of time limits. For leisure reading and independent studying, one generally reads without time constraints to finish the text. However, during a test or in a time-limited situation, there are time constraints for the time one can read. This is distinctive from pacing in that one can read a unit of text (e.g., a sentence) self-paced, but only has a limited amount of time with the text so may not be able to re-read or finish the text in the allotted time. Because reading aloud is a common accommodation in testing, which is time limited, it is important to consider whether studies had time limits (Spiel et al., 2019). Furthermore, time limits have been noted a key moderator in a previous meta-analysis on reading medium (paper or screens; Delgado et al., 2018).

Reading in one's second or additional language is considered more challenging than reading in one's first/native language. One method proposed to support second language readers with these challenges is reading while listening (Zhang & Zou, 2022). Supporters of reading while listening for second language learners argue the audio assists with word recognition skills by being able to connect the phonologies (sounds) and orthographies (spellings; Chang & Millett, 2014; Tragant & Valbona, 2018). In addition, the audio provided when reading while listening may provide contextual cues through tone for how to interpret the text as well as through pauses guiding text segmentation (Conklin et al., 2020; Tragant et al., 2016).

The type of voice in the audio for reading while listening may be an important factor in its effect. According to the voice effect or voice principle, audio should be provided by a human voice rather than a computer-generated voice (also referred to as a text-to-speech voice or machine-generated voice; Mayer, 2014). This is based on a review of studies indicating that narration with human voices had better learning outcomes than narration with computer-generated voices (Mayer, 2014). Potential explanations for the voice effect are that human voices are more pleasant to listen to and require less effort to understand than computer-generated voices (Kalyuga, 2011; Mayer et al., 2003). However, modern advances in computer-generated voices leading to better quality may have attenuated the voice effect and findings between human and computer-generated voices may be similar (Craig & Schroeder, 2019).

The genre of the text in the study may be an important factor. Broadly speaking, genre in text comprehension is categorized as narrative or expository. Narrative texts are generally easier to comprehend than expository texts because narrative texts have a more uniform structure, less esoteric vocabulary than expository texts (Clinton et al., 2020; Mar et al., 2021). In addition, narrative texts tend to incorporate background knowledge that tends to be relatable to readers such as everyday experiences (e.g., eating at a restaurant) whereas expository texts tend to involve background knowledge that is domain specific (e.g., geological formations; Cain et al., 2004; Graesser et al., 2004). Moreover, genre may be important when considering reading while listening to text because the audio may provide contextual cues with tone and volume that could assist readers with following the plot and character developments of narrative texts (Best, 2021).

THE CURRENT STUDY

Given the conflicting findings in studies comparing reading while listening to reading alone coupled with the increasing access to text with accompanying audio, a meta-analysis is needed to synthesize and interpret the current body of literature. Such a meta-analysis would be informative as to whether readers without reading disabilities should be advised to use audio features when reading (note that Wood et al.'s 2018 meta-analysis indicated that readers with disabilities benefit from audio-assisted reading). Previous meta-analyses have been conducted with one focusing on readers with disabilities (Wood et al., 2018) as well as two comparing reading and listening comprehension (Clinton-Lisell, 2022; Singh & Alexander, 2022), and one on verbal redundancy which also included reading while listening to listening alone or having partial overlap between text and audio (Adesope & Nesbit, 2012). The current meta-analysis builds on this prior work by comparing conditions in which the entire text is both read and listened to (as is the feature in many electronic reader platforms) to conditions in which the entire text is only read (as has been the traditional approach to independent reading). This meta-analysis is guided by the following research questions:

1. What is the overall effect of reading-while-listening compared to only reading on reading comprehension?
2. How does this effect vary depending on characteristics of the reading situation (self- or experimenter-paced), the reader (first or second language), text (narrative, expository, or both), and audio (human- or computer-generated voice)?

METHOD

Studies comparing text comprehension when reading to reading while listening were systematically searched for. The inclusion criteria were 1) at least one condition in which participants read while listening to audio of the all of the written text and at least one condition in which participants read the text without audio, 2) there was a measure of reading comprehension, 3) participants had sufficient skills to read independently and were not learning how to decode, 4) participants did not have learning disabilities or physical disabilities that could affect vision or hearing, 5), participants were either randomly assigned to condition (between-subjects) or texts were counterbalanced (within-subjects), 6) the texts and assessment were in the same language (due to the additional cognitive load of translation, Nawal, 2018), 7) the texts were the same in both conditions; and 8) sufficient statistics to calculate effect sizes for comprehension findings were available. Due to the linguistic backgrounds of the researchers on this project, only studies written in English could be included.

The systematic search for relevant studies was begun with citation searches of the following library databases: Web of Science, Scopus, ERIC, Proquest dissertations and theses, and PsycInfo using the search strings such as "listening while reading" OR "reading while listening" OR "read and listen" OR "listen and read" and “audio-assisted reading.” This led to a total of 2,273 citations of which 51 were duplicates. After duplicates were deleted, the remaining 2,225 citations were screened by at least two researchers based on the title and abstracts using Abstrackr (Wallace et al., 2012). Based on the title and abstract screening, the full texts of 62 reports were coded for inclusion criteria. Of these, 12 studies met the inclusion criteria. An ancestral search of the references of these studies (backwards search) was conducted which yielded another study. A forwards search of studies citing these studies was conducted which yielded an additional 13 reports. The references of previous reviews comparing reading and listening comprehension were examined, which yielded an additional two studies (Clinton-Lisell, 2022; Singh & Alexander, 2022). A total of 28 reports with 30 independent studies (total N = 1945; Kopp & D'Mello, 2016, had three separate studies) was included in the meta-analysis. The systemic review process is shown in Figure 1.

Coding

To prepare the reports for analyses including moderator analyses, details about the bibliographic and methodological details of each study was coded. For bibliographic details, the authors and date of publication for each study was entered. The methodological details coded were based on characteristics of the participants, texts, procedure, and reading comprehension assessment. Specifically, the coding included the age and language background of the participants (whether they were reading in their first language, L1, or additional language, L2), the genre of the texts (narrative, expository, or both/uncertain), whether the voice was human or computer generated, the pacing of the reading and reading-while-listening conditions (self or experimenter paced), the time allotted for reading (unlimited or limited) and nature of the assessment(s) for reading comprehension (description of items and modality). Two researchers coded the reports with 25% in common ($\kappa = .91$). See Table 1 for a summary of included studies.

Statistical Procedures

Effect sizes were calculated for each measure of reading comprehension in each included study. To correct for bias due to sample size, Hedges g was used as an effect size and calculated using the Meta-Essentials tools (Suurmond et al., 2017). A positive Hedges’ *g* indicates better performance for reading while listening compared to reading alone. Both within and between subjects studies were included (Borenstein et al., 2009). In studies in which there were multiple measures of reading comprehension, the dependencies of these effect sizes within a study were accounted for using robust variance estimation (RVE) with a standard assumed correlation of .8 (Tanner-Smith et al., 2016). This allows for the unique information from each effect size to be considered without inflating the contributions of a given study. The degree of variation in effect sizes was examined using the I^2 index. The I^2 index is a measure of effect size heterogeneity from 0 to 100 with a higher number indicating more variability (Lin, 2020). An I^2 above 20 would necessitate moderator analyses to determine sources of variability (Bloch, 2014). See Figure 2 for a forest plot of all effects sizes included in this meta-analysis. The dataset of effect sizes and R code for this meta-analysis are available on Open Science Framework (Clinton-Lisell, 2022).

Figure 1
Flow diagram of the systematic review process

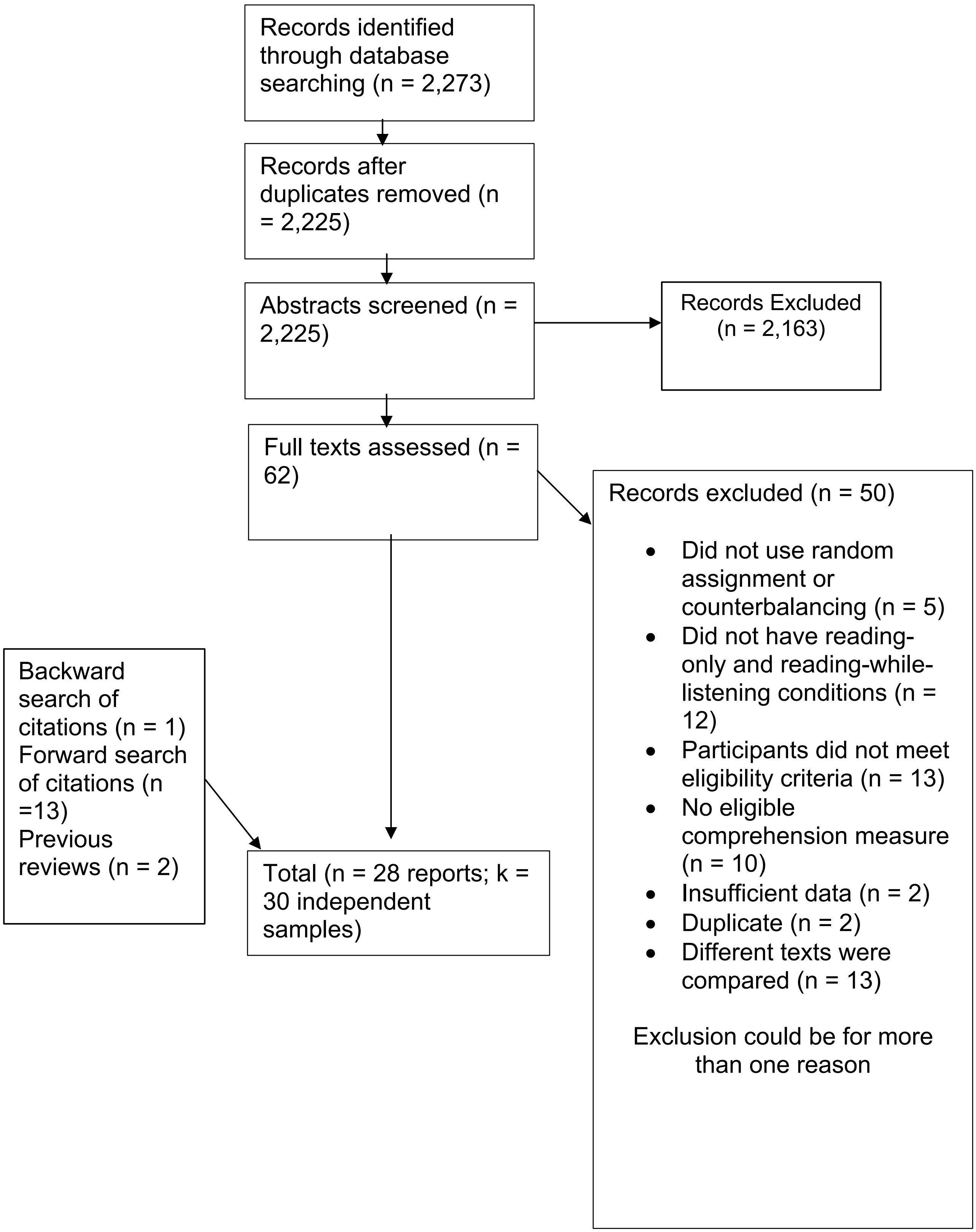

Figure 2
Forestplot of effect sizes by study and measure

Study	TE	seTE	g	95%-CI
Alvarez-Alonso et al., 2021, open-ended questions	0.36	0.1700	0.36	[0.03; 0.69]
Ari & Calandra, 2021, questions	-0.51	0.1500	-0.51	[-0.80; -0.22]
Baron et al., 1993, learning	0.16	0.3100	0.16	[-0.45; 0.77]
Chen, 2021, incidental vocabulary acquisition	0.73	0.2900	0.73	[0.16; 1.30]
Conklin et al. L1, 2020, L1 participants	-0.23	0.1900	-0.23	[-0.60; 0.14]
Conklin et al. L2, 2020, L2 participants	-0.59	0.2000	-0.59	[-0.98; -0.20]
Holmes, 1985, gist	0.09	0.1423	0.09	[-0.19; 0.37]
Holmes, 1985, literal	-0.52	0.1517	-0.52	[-0.82; -0.23]
Holmes, 1985, inferential	-0.66	0.1570	-0.66	[-0.96; -0.35]
Holmes, 1985, comparison	-0.10	0.1423	-0.10	[-0.38; 0.18]
Holmes & Allison, 1986, literal	-0.19	0.1432	-0.19	[-0.47; 0.09]
Holmes & Allison, 1986, inferential	-0.57	0.1536	-0.57	[-0.88; -0.27]
Holmes & Allison, 1986, application	-0.29	0.1450	-0.29	[-0.57; -0.00]
Keelor et al., 2020, comprehension	1.03	0.3700	1.03	[0.30; 1.76]
Keelor et al., 2018, comprehension	0.82	0.2100	0.82	[0.41; 1.23]
Knoop-van Campen et al., 2018, recall, short term	0.07	0.1600	0.07	[-0.25; 0.38]
Knoop-van Campen et al., 2018, recall, long term	0.23	0.1600	0.23	[-0.09; 0.54]
Knoop-van Campen et al., 2018, transfer, short term	0.14	0.1600	0.14	[-0.17; 0.46]
Knoop-van Campen et al., 2018, transfer, long term	0.14	0.1600	0.14	[-0.18; 0.45]
Knoop-van Campen et al., 2019, recall, short term	0.14	0.2200	0.14	[-0.29; 0.57]
Knoop-van Campen et al., 2019, recall, long term	-0.09	0.2100	-0.09	[-0.50; 0.32]
Knoop-van Campen et al., 2019, transfer, short term	-0.17	0.2200	-0.17	[-0.60; 0.26]
Knoop-van Campen et al., 2019, transfer, long term	0.57	0.2300	0.57	[0.12; 1.02]
Knoop-van Campen et al., 2020, transfer	-0.21	0.1356	-0.21	[-0.48; 0.05]
Knoop-van Campen et al., 2020, retrieval	-0.05	0.1482	-0.05	[-0.34; 0.24]
Knoop-van Campen et al., 2022, summary	0.00	0.2400	0.00	[-0.47; 0.47]
Knoop-van Campen et al., 2022, open-ended questions	0.67	0.2600	0.67	[0.16; 1.18]
Knoop-van Campen et al., 2022, statement	0.00	0.2400	0.00	[-0.47; 0.47]
Kopp & D'Mello, Exp 1, 2016, comprehension	0.25	0.1600	0.25	[-0.06; 0.56]
Kopp & D'Mello, Exp 2, 2016, comprehension	0.15	0.2100	0.15	[-0.26; 0.56]
Kopp & D'Mello, Exp 3, 2016, recall, self-paced	0.14	0.1900	0.14	[-0.23; 0.51]
Kopp & D'Mello, Exp 3, 2016, recall, experimenter-paced	0.11	0.2100	0.11	[-0.30; 0.52]
Koroghlanian & Sullivan, 2000, multiple-choice test	-0.21	0.2100	-0.21	[-0.62; 0.20]
Košak-Babuder et al., 2019, difficult text	0.15	0.0700	0.15	[0.01; 0.29]
Košak-Babuder et al., 2019, easy text	-0.02	0.0700	-0.02	[-0.16; 0.12]
Liu et al., 2015, Story A recall	0.55	0.2300	0.55	[0.10; 1.00]
Liu et al., 2015, Story B recall	0.49	0.2200	0.49	[0.06; 0.92]
Liu et al., 2015, Story A comprehension	0.45	0.2200	0.45	[0.02; 0.88]
Liu et al., 2015, Story B comprehension	0.65	0.2300	0.65	[0.20; 1.10]
Montali & Lewandowski, 1996, less skilled	0.44	0.1709	0.44	[0.10; 0.77]
Montali & Lewandowski, 1996, average	0.20	0.1646	0.20	[-0.12; 0.52]
Moussa-Inaty et al., 2019, acquisition (materials present)	0.19	0.2497	0.19	[-0.30; 0.68]
Moussa-Inaty et al., 2019, testing (materials absent)	0.10	0.2493	0.10	[-0.39; 0.59]
Rogowsky et al., 2016, immediate	0.04	0.2529	0.04	[-0.46; 0.53]
Rogowsky et al., 2016, delayed	-0.24	0.2538	-0.24	[-0.74; 0.26]
Sannomiya, 1982, easy text	0.12	0.4300	0.12	[-0.72; 0.97]
Sannomiya, 1982, difficult text	0.27	0.4300	0.27	[-0.57; 1.12]
Sannomiya, 1984, slow	0.57	0.4600	0.57	[-0.33; 1.47]
Sannomiya, 1984, fast	0.36	0.4500	0.36	[-0.52; 1.25]
Schmitt et al., 2011, factual	0.09	0.2300	0.09	[-0.36; 0.55]
Schmitt et al., 2011, inferential	0.20	0.3200	0.20	[-0.43; 0.83]
Schüler et al. , 2013, system-paced recall	-0.23	0.3100	-0.23	[-0.84; 0.38]
Schüler et al. , 2013, system-paced transfer	0.15	0.3100	0.15	[-0.46; 0.76]
Schüler et al. , 2013, learner-paced recall	-0.22	0.3100	-0.22	[-0.83; 0.39]
Schüler et al. . 2013, learner-paced transfer	0.17	0.3100	0.17	[-0.44; 0.78]
Serrano & Pellicer-Sanchez, 2019, comprehension	0.07	0.1600	0.07	[-0.24; 0.38]
Taake, 2009, human voice, reading time	0.05	0.1200	0.05	[-0.19; 0.29]
Taake, 2009, synthetic voice, reading timed	0.06	0.1200	0.06	[-0.18; 0.30]
Taake, 2009, human voice, reading self-paced	0.00	0.1200	0.00	[-0.24; 0.24]
Taake, 2009, synthetic voice, reading self-paced	0.00	0.1200	0.00	[-0.24; 0.24]
Teng, 2018, incidental vocabulary acquisition	1.01	0.2700	1.01	[0.48; 1.54]
Verlaan & Ortlieb, 2012, comprehension	0.38	0.1000	0.38	[0.18; 0.58]

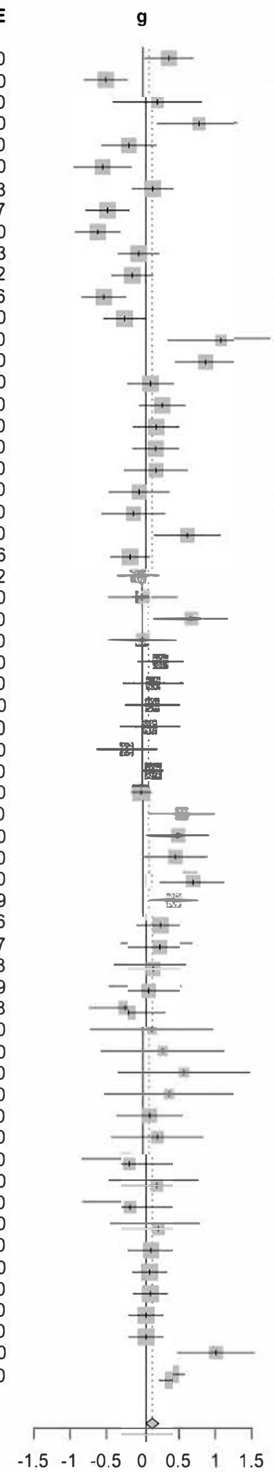

Table 1
Summary of Studies

Authors (date)	Participants and study design	Texts, medium, and audio	Timing and pacing	Comprehension measure
Alvarez-Alonso et al. (2021)	141 seventh and eighth grade students (L1); between subjects	Expository; computer voice	Experimenter-paced reading and reading-while-listening; time limited	Open-ended inferential questions (written)
Ari & Calandra (2021)	60 college students (L1); within-subjects	Expository; human voice	Self-paced reading; experimenter-paced reading while listening; time limited	Both verbatim and inference questions (written)
Barron et al. (1993)	40 college students (L1); between subjects	Expository; human voice	Self-paced reading and reading while listening	Test of content (written)
Chen (2021)	50 college students (L2); between subjects	Narrative; human voice	Experimenter-paced reading and reading-while-listening; time limited	Incidental vocabulary learning from the text (written)
Conklin et al. (2020)	32 (L2) and 31(L1) college students;	Narrative; human voice	Self-paced reading and reading while listening; no time limits	Yes or no general comprehension questions (written)
Holmes (1985)	48 college students (L1); within-subjects	Expository; human voice	Self-paced reading; experimenter-paced reading while listening; no time limits for reading	Open-ended questions designed require different levels of understanding (written)
Holmes & Allison (1986)	48 fifth grade students (L1); within-subjects	Expository; human voice	Self-paced reading; experimenter-paced reading while listening; no time limits for reading	Open-ended questions designed require different levels of understanding (written)

Keelor et al. (2018)	29 children ages 8-12 years (L1); within-subjects	Narrative and expository; computer voice	Self-paced reading; experimenter-paced reading while listening; no time limits for reading (only allowed to read once)	Multiple-choice questions (oral and written)
Keelor et al. (2020)	10 children ages 8-11 years (L1); within-subjects	Expository; computer voice	Self-paced reading; experimenter-paced reading while listening; no time limits for reading (only allowed to read once)	Multiple-choice questions (oral and written)
Knoop-van Campen et al. (2018)	38 11-year-old children (L1); within-subjects	Narrative; human voice	Self-paced reading and reading while listening	Retention through free recall. Transfer through open-ended application questions (oral)
Knoop-van Campen et al. (2019)	20 elementary school students (L1); within-subjects	Expository; human voice	Self-paced reading and reading while listening; no time limits	Retention through free recall. Transfer through open-ended application questions (oral)
Knoop-van Campen et al. (2020)	44 college students (L1); within-subjects	Expository; human voice	Self-paced reading and reading while listening; no time limits	Retention through recall. Transfer through open-ended application questions (written)
Knoop-van Campen et al. (2022)	16 eighth-grade students (L1); within-subjects	Expository; human voice	Self-paced reading and reading while listening; no time limits	Summary (fill in missing words), open-ended questions with short answers, true/false statements (written)
Kopp & D'Mello, Exp. 1, (2016)	51 adults (L1); within-subjects	Narrative; human voice	Self-paced reading; experimenter-paced reading while listening	Multiple-choice questions (written)

Kopp & D'Mello, Exp. 2, (2016)	60 adults (L1); between subjects	Narrative; human voice	Self-paced reading; experimenter-paced reading while listening	Multiple-choice questions (written)
Kopp & D'Mello, Exp. 3, (2016)	181 adults (L1); between subjects	Narrative; human voice	Different conditions for self-paced and experimenter-paced reading; experimenter-paced reading while listening	Free recall (written)
Koroghlanian & Sullivan (2000)	87 college students (L1); between subjects	Expository; human voice	Self-paced reading and reading while listening	Multiple-choice test of content
Košak-Babuder et al. (2019)	233 children ages 11-13 (L2); within-subjects	Expository; human voice	Self-paced reading; experimenter-paced reading while listening; time limit for reading	Comprehension questions (written)
Liu et al. (2015)	80 college and graduate students (L1); between subjects	Narrative; computer voice	Experimenter-paced reading and reading-while-listening	Recall and short-answer comprehension questions
Montali & Lewandowski (1996)	36 eighth and ninth grade students (L1); within-subjects	Expository; human voice	Self-paced reading; experimenter-paced reading while listening; no time limits for reading	Short-answer comprehension questions (oral)
Moussa-Inaty et al. (2019)	94 college students (L2); between subjects	Expository; human voice	Self-paced reading; experimenter-paced reading while listening; time limit for reading	Multiple-choice questions with and without materials present (written)
Rogowsky et al. (2016)	61 adults with college education (L1); between subjects	Expository; human voice	Self-paced reading; experimenter-paced reading while listening; no time limits for reading	Multiple-choice questions (written)

Sannomiya (1982)	40 college students (L1); between subjects	Expository; human voice	Self-paced reading; experimenter-paced reading while listening; time limit for reading	Free recall (written)
Sannomiya (1984)	36 college students (L1); between subjects	Expository; human voice	Experimenter-paced reading and reading-while-listening; time limited	Free recall (written)
Schmitt et al. (2011)	25 middle-school students (L1); within-subjects	Genre not stated; computer voice (TTS software)	Self-paced reading; experimenter-paced reading while listening; no time limits for reading	Factual and inferential comprehension questions (written)
Schüler et al., Exp. 2, (2013)	82 college students (L1); between subjects	Expository text; human voice	Different conditions for self-paced and experimenter-paced reading; experimenter-paced reading while listening	Recall and transfer questions (written)
Serrano & Pellicer-Sánchez (2019)	35 fifth grade students (L2); within-subjects	Narrative text; human voice	Self-paced reading and reading while listening; no time limits for reading	Short-answer questions (oral)
Taake (2009)	66 college students (L1); within-subjects	Narrative; different conditions for human and computerized voices	Different conditions for self-paced and experimenter-paced reading and reading while listening; time limits for reading	General comprehension multiple-choice questions (written)
Teng (2018)	60 college students (L2); between subjects	Narrative; human voice	Self-paced reading; experimenter-paced reading while listening; time limit for reading	Incidental vocabulary learning from text (written)

Verlaan & Ortlieb (2012)	110 tenth-grade students (L1); within-subjects	Narrative; human voice	Self-paced reading; experimenter-paced reading while listening;	Short-answer questions (written)

Results

The overall main effect on comprehension when comparing reading to reading while listening was estimated using RVE based on 30 studies and 62 effect sizes. The findings indicated a positive effect on comprehension for reading while listening over reading alone, $g = 0.18$, SE = 0.07, 95% CI = [0.04, 0.32], $p = .01$. Hedges' g is interpreted as 0.1 being trivial and 0.2 being a small effect; therefore, the difference between reading while listening and reading only on comprehension would be considered trivial. The I^2 was 99.80 indicating a very high degree of variability across studies.

Publication bias

Publication bias occurs when statistically significant results are more likely to be published. This threatens the generalizability of finding from meta-analyses because studies without statistically significant effects may not be disseminated and findable in a systematic search. Potential issues of publication bias were examined in two methods in this meta-analysis. The first method was to generate a funnel plot from the effect sizes. The funnel plot can be seen in Figure 3. In a funnel plot, the effect sizes are plotted on the y-axis with smaller studies based on their treatment effect size standard errors towards the bottom. The effect sizes themselves are distributed along the x-axis with a vertical line indicating the mean effect size. A symmetrical distribution and smaller studies being similarly away from the mean as larger studies would indicate a lack of publication bias. Based on the funnel plot in Figure 3, there is some asymmetry in which there are small studies with effect sizes greater than the mean that are not mirrored in the space with effect sizes less than the mean. This indicates publication bias. However, larger studies (with smaller standard errors of treatment effect sizes) are similar distances from the mean as smaller studies (with the exception of two studies focused on struggling readers; Keelor et al., 2018, & Keelor et al., 2020). To further investigate publication bias, a second method was used: Egger's test of the intercept using the "demetar" package in R; Harrer et al., 2019). In this test, a significant intercept is indicative of asymmetry and subsequently publication bias. Egger's test of the intercept of this funnel plot did not indicate asymmetry, $t = 1.56$, $p = .12$. Taken together, these findings indicate that publication bias may have been a factor but was unlikely to have a substantial effect on the meta-analytic findings.

Meta-Regression

The high degree of variability across effect sizes necessitates a moderator analysis. The moderators considered were study design (between or within-subjects), pacing of the reading condition (self- or experimenter-paced), pacing of the reading-while-listening condition (self- or experimenter-paced), the genre of the texts, the native language status of the participants (first or second/additional language), the voice (human or computer), and time limits (unlimited or limited). To conduct the meta-regression model, the package "robumeta" in R was used (Fisher & Tipton, 2015). Based on the outcome of the meta-regression (see Table 2), the pacing of the reading condition was a significant moderator. To further examine this, two additional RVE analyses were conducted to examine the main effects in studies with self-paced reading and in studies with experimenter-paced reading. In the studies with self-paced reading (24 studies, 47 effect sizes), there was no reliable difference between reading and reading while listening, $g = 0.06$, SE = 0.06, 95% CI = [-0.07, 0.19], $p = .34$. In contrast, in studies in which the reading condition had experimenter pacing (9 studies, 15 effect sizes), there was better comprehension of the text in the reading-while-listening condition, $g = 0.41$, SE = 0.12, 95% CI = [0.13, 0.70], $p = .01$. Therefore, the overall positive effect noted in the initial RVE analysis of all included studies was likely driven by the studies in which the reading condition had experimenter pacing.

Figure 3

Funnel plot of effect sizes

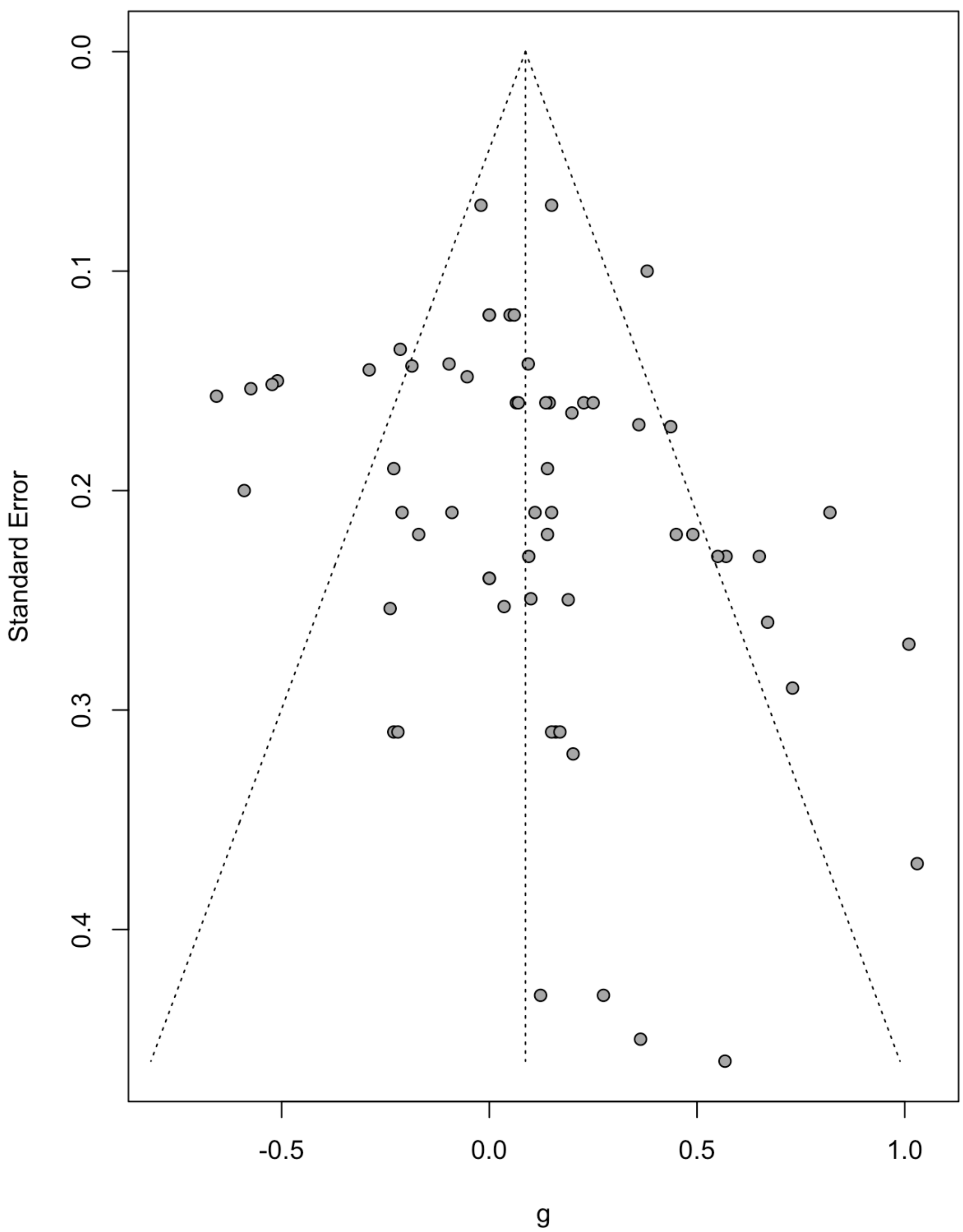

Table 2
Meta-regression results

	Beta	SE	*T*	Dfs	*p*	95% CI Lower	95% CI Upper
Intercept	0.03	0.15	0.22	12.10	.83	-0.29	0.36
Design	-0.07	0.13	-0.54	12.25	.60	-0.36	0.21
Reading pace	0.42	0.18	2.30	10.00	.04	0.01	0.82
RWL pace	0.09	0.17	0.49	14.00	.63	-0.29	0.46
Genre	-0.03	0.10	-0.26	9.63	.80	-0.24	0.19
L1 or L2	0.28	0.23	1.23	7.28	.26	-0.26	0.83
Voice	0.18	0.16	1.12	9.33	.29	-0.18	0.53
Time limits	-0.13	0.17	-0.79	10.09	.45	-0.50	0.24

Note. Design = between-subjects (coded 0) or within-subjects (coded 1). Reading pace = reading-only condition was self-paced (coded 0) or experimenter paced (coded 1). RWL pace = reading-while-listening condition was self-paced (coded 0) or experimenter paced (coded 1). Genre = narrative texts (coded 0), expository texts (coded 1), or mixed/unknown (coded 2). L1 or L2 = texts were in participants' native language (coded 0) or additional language (coded 1). Voice = the voice for the reading-while-listening condition was human (coded 0) or computer generated (coded 1), time limits = participants had no time limits for reading (coded 0) participants had time limits for reading (coded 1). SE = standard error. *t* = t-test value. Dfs = degrees of freedom. *p* = significance. 95% CI Lower = 95% confidence interval lower limit. 95% CI Upper = 95% confidence interval upper limit.

Discussion

The purpose of this meta-analysis was to synthesize findings on comprehension comparing reading to reading while listening. Based on the overall effect size, there is a trivial, but statistically significant benefit of reading while listening over reading alone. However, based on a moderator analysis, the benefit of reading while listening appears to be constrained to studies in which the reading-only condition's text was presented at the experimenter's pace (rather than self-paced as is typically done when reading). None of the other moderators examined (reading-while-listening condition pacing, native language/second language, voice, or genre) reliably varied the effect of reading while listening on comprehension compared to reading alone.

To put into context the effect sizes noted in this meta-analysis, it is helpful to consider other effect sizes when comparing different conditions for reading on comprehension and learning from text. For examples, the effect sizes for the benefit of paper over screens on reading range from g = 0.21 to g = 0.25 (Clinton, 2019; Delgado et al., 2018; Kong et al., 2018), the negative effect of seductive details (interesting, but irrelevant information in materials) on learning is g = 0.33 (Sundararajan & Adesope, 2020), the benefit of refutation texts (addressing scientific misconceptions by refuting them) on learning is g = 0.41 (Schroeder et al., 2022), and for the benefit of graphics on text comprehension is g = 0.39 (Guo et al, 2020). Compared to these effect sizes, the overall effect of reading while listening on comprehension (g = 0.18) is quite small.

There were competing theoretical views on whether reading while listening would have a negative or positive effect on reading comprehension. One view was the dual channel assumption in which information is processed by separate auditory and visual channels. Having information in both visual and auditory modalities would be beneficial in this view because the two channels could more effectively process the text (Mayer, 2005; Penney, 1989). The other view was cognitive load theory in which redundant information, such as presenting information in two modalities, would overload limited cognitive resources and diminish learning (Sweller, 2020). The findings from this meta-analysis indicate support for the dual channel assumption because there was a benefit of reading while listening. However, there were individual studies with negative effects that may be explained by cognitive load theory. For example, Ari and Calandra's (2021) procedure mimicked taking a high-stakes test in a college classroom and found a negative effect of reading while listening. In their sample, students were enrolled in courses specifically designed to prepare them for high stakes reading tests. One potential explanation is the anxiety of being in a high stakes test added to the cognitive load making redundant information by modality overwhelming to process (Putwain & Symes, 2018). Another potential explanation was that these students were accustomed to practicing for reading tests without audio and the addition to audio was unusual and added to their cognitive load. These considerations are merely conjecture without data to support them but may provide avenues for future inquiry on reading while listening.

The role of pacing was critical in determining the size of the effect of reading while listening. In studies in which readers read at their own pace in the reading-only condition, there were no reliable differences between reading while listening and reading. However, if the text needed to be read at a pace set by the experimenter, the conditions were such that participants in both reading-while-listening and reading-only conditions read the texts at the same pace. This could be explained by the dual channel assumption (Mayer & Moreno, 2003). When both the reading-while-listening and reading-only conditions are experimenter paced, then being able to process information in both visual and audio channels is beneficial. One reason for this could be that experimenter-pacing reduces the amount of text that can be seen at one time, subsequently it is more difficult for readers to look back to make connections with the previously-read text. Making connections between ideas in a text is critical for developing the textbase in the construction-integration model (Kintsch, 1998). Having the audio provided another channel of information; therefore, connections could be made between the two channels (Mayer & Moreno, 2003). Another possible explanation is that having the information in auditory form allowed it to be stored and retrieved from echoic memory (i.e., the 3-4 seconds of auditory information automatically stored) if the text was not visually read in the time it was displayed during experimenter-paced presentation (Bijsterveld, 2015). Having a limited amount of time itself did not vary the effect of reading while listening on comprehension, which indicates that not being able to pace oneself was critical for reading while listening to improve comprehension.

Self-pacing in reading while listening did not appear to affect reading-while-listening's effect on comprehension, but it was used in only eight studies, making for a small sample size. Moreover, some researchers noted that fewer participants in reading-while-listening conditions actually used features allowing them to re-read and listen to the text compared to participants in reading-only conditions (Barron et al., 1993; Schüler et al., 2013). Future research in which readers receive modeling on how to replay audio features to support their understanding may be useful to further understand if self-pacing for reading while listening would support comprehension.

Reading while listening has been advocated to support second/additional language reading (Chang & Millett, 2014; Tragant & Valbona, 2018). However, there were no differences in effects based on first or second language reading based on the meta-regression. When examining the forest plot, two studies with particularly large positive effects of reading while listening focused on second language incidental vocabulary acquisition (learning new words from context without explicit vocabulary instruction; Chen, 2021; Teng, 2018). Considering that reading while listening is thought to aid in word recognition by providing both the written and aural form of words, it is possible that providing the text in two modalities assisted in learning new vocabulary within the text (Chang & Millett, 2014; Tragant, & Valbona, 2018). Because there were no studies in this meta-analysis of incidental vocabulary acquisition in one's first/native language, it is uncertain if these findings are specific to second language vocabulary or incidental vocabulary acquisition in general. Furthermore, with only two studies, it is premature to assume any particular benefit of reading while listening on second language incidental vocabulary acquisition.

Reading while listening may be particularly helpful for struggling readers who have difficulty decoding (Barth et al., 2015; Spencer & Wagner, 2018). Because the language is provided in two modalities, struggling readers do not have to overly rely on one modality and can focus on comprehension. It was not possible to obtain the reading proficiencies of all the samples in every included study; however, it is useful to examine studies in which struggling readers were the sample or distinguished in a subsample. Keelor and colleagues' studies (2018, 2020) consisted of struggling readers and large benefits of reading while listening compared to reading only for comprehension were noted. In studies in which struggling readers were a subset of the sample, reading while listening appeared to be particularly helpful for struggling readers (Alvarez-Alonso et al., 2021; Montali & Lewandowski, 1996; Verlaan & Ortlieb, 2012). In future inquiry, it may be fruitful examine how reading while listening can be used to support reading comprehension in readers with lower levels of proficiency, but do not have reading disabilities.

According to the voice effect (also referred to as the voice principle), learning is better when narration if from a human voice than a computer-generated voice (Mayer et al., 2003). This is based on a review of previous evidence comparing studies with human and computer-generated voices (Mayer, 2014). However, there were no reliable differences in reading while learning effects based on the voice being human or computer generated. Indeed, one study in which human and computer-generated voices were compared did not find a difference in learning between the two voices (Taake, 2009). This may indicate that the voice effect is not as robust as once thought (Craig & Schroeder, 2019). Notably, the lack of learning differences due to voice are informative as to the utility of built-in text-to-speech features on various software. This may be helpful guidance for teachers who may wish to incorporate reading while listening in their instruction.

One concern about providing accommodations such as reading while listening to students with disabilities is that it gives these students an unfair advantage (Lovett, 2020; Vidal Rodeiro & Macinska, 2022). In other words, is it equitable to provide students with disabilities audio to assist with reading, but not other students? This question becomes more salient when considering high-stakes reading assessments. The findings from this meta-analysis indicate that reading while listening only provides an advantage to readers without known disabilities if the reading is at the experimenter's pace. Having a time limit itself for reading did not yield a benefit for reading while listening. Because reading is almost always self-paced, albeit with time limits in high-stakes assessments, it does not appear that allowing reading while listening gives students with disabilities an unfair advantage. Instead, providing audio assistance while reading may foster equitable learning and assessment.

Limitations and Future Directions

There were limitations to this meta-analysis that need to be noted. Notably, only studies disseminated in English were considered and subsequently an unknown number of studies were not considered for inclusion. In addition, only studies comparing comprehension of the texts used directly in the intervention (i.e., reading while listening) were considered. Studies of longer interventions designed to improve reading comprehension across texts using reading while listening were not considered (e.g., Chang et al., 2018). Therefore, conclusions about the efficacy of long-term reading-while-listening interventions to build fluency and comprehension cannot be made based on the results of this meta-analysis.

Conclusion

Reading while listening has been a technique to support comprehension with conflicting theoretical views. The findings from this study indicate reading while listening supports comprehension when text is read at a pace set by the experimenter, but not when reading at one's own pace. These findings support the dual channel approach, in which auditory and visual information are processed in separate channels (Mayer & Moreno, 2003) more than cognitive load theory (Kalyuga, 2011), in which presenting information in two modalities is redundant and overwhelming to limited cognitive resources. Reading while listening may also be particularly helpful for struggling readers and for learning second language vocabulary, but the current evidence base is too limited to make such generalizations. Overall, if students wish to use audio-assisted reading, they should not be discouraged to do so.

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