Applied Cognitive Psychology, *Appl. Cognit. Psychol.* **29**: 669–679 (2015)
Published online 24 July 2015 in Wiley Online Library (wileyonlinelibrary.com) **DOI**: 10.1002/acp.3149

Partial Verbal Redundancy in Multimedia Presentations for Writing Strategy Instruction

ROD D. ROSCOE*, MATTHEW E. JACOVINA, DANIELLE HARRY, DEVIN G. RUSSELL and DANIELLE S. MCNAMARA

Human Systems Engineering, The Polytechnic School, Ira A. Fulton Schools of Engineering, Arizona State University, Mesa, AZ USA

Summary: Multimedia instructional materials require learners to select, organize, and integrate information across multiple modalities. To facilitate these comprehension processes, a variety of multimedia design principles have been proposed. This study further explores the redundancy principle by manipulating the degree of partial redundancy between written and narrated content. Ninety high school students learned about cohesion via animated lesson videos from the Writing Pal intelligent tutoring system. Videos were crafted such that narrated and onscreen written content overlapped by 10%, 26%, or 50%. Across conditions, students gained significantly in their knowledge of cohesion-building strategies and the effects of cohesion on writing quality. However, degree of redundancy did not influence learning gains. Additionally, although more-skilled readers outperformed less-skilled readers, reading skill did not interact with the degree of redundancy. These results provide evidence that a broad range of partially redundant multimedia materials may be viable instructional tools that benefit diverse learners. Copyright © 2015 John Wiley & Sons, Ltd.

Instructional materials are often presented in multimedia formats where learners must simultaneously attend to multiple modalities, integrating written (i.e., visual) and spoken (i.e., auditory) information (Adesope & Nesbit, 2012; Mayer, 2009). Online courses might offer lecture materials in which presentations are accompanied by prerecorded narration (e.g., Cramer, Collins, Snider, & Fawcett, 2007). Similarly, many intelligent tutoring systems (ITSs) and other computer-based learning environments incorporate instructional text, diagrams, and dialogs that are spoken or explained by animated pedagogical agents (Craig, Driscoll, & Gholson, 2004; Craig, Gholson, & Driscoll, 2002; Johnson, Rickel, & Lester, 2000). For example, ITSs such as AutoTutor (Graesser et al., 2004), iSTART (Jackson & McNamara, 2013), and Writing Pal (W-Pal; Roscoe & McNamara, 2013) use agents to provide spoken explanations of subject matter content, strategies, and feedback. Likewise, teachable agents systems, such as Betty's Brain (e.g., Segedy, Kinnebrew, & Biswas, 2013), and game-based systems, such as BiLAT (e.g., Lane, Hays, Core, & Auerbach, 2013) and Crystal Island (e.g., Rowe, Shores, Mott, & Lester, 2011), combine text and narration to engage learners in productive dialogs and narratives with the animated characters while also providing instructional content and feedback.

Given the ubiquity of multimedia instructional tools that combine text and narration, an important area of research has been to establish key design guidelines for creating such materials. With this work, Mayer and colleagues (Mayer, 2005; Mayer, 2009; Mayer & Moreno, 2003; Moreno & Mayer, 1999; also refer to Chandler & Sweller, 1991; Sweller, Ayres, & Kalyuga, 2011) have outlined cognitive theories of multimedia learning along with several principles for managing the learning challenges that arise. In brief, it has been argued that processing of visual (i.e., printed text and images) and auditory (i.e., sounds and narration) information is handled via separate but related channels that are limited in capacity. Both channels rely on attention processes to select where to look or listen, organizational processes to construct coherent representations from presented words and images, and integration processes that merge concepts and representations within and across each modality to form an understanding of the content. These active learning processes are essential to successful learning. Students must process the material deeply through inference generation and the organization of ideas if the objective is for them to remember, understand, or transfer the information (Eason, Goldberg, Young, Geist, & Cutting, 2012; Magliano & Millis, 2003; McNamara & Kintsch, 1996; McNamara, O'Reilly, Best, Ozuru, 2006). An important caveat, however, is that learners can be overwhelmed by multiple or competing cognitive demands. Findings from multimedia learning research demonstrates that the extent to which instructional materials require higher levels of selection, organization, and integration across one or more modalities can lead to increasing difficulty or cognitive load that hinders learning (Leahy, Chandler, & Sweller, 2003; Leahy & Sweller, 2011). Similarly, the benefits of multimedia instructional materials may also depend on learners' individual characteristics such as reading skill and prior knowledge (O'Reilly & McNamara, 2007; Ozuru, Dempsey, & McNamara, 2009). Consequently, optimizing learning via materials that require integrative processing presents a challenging balancing act for educators.

A central aim for multimedia design is to support effective processing and comprehension by mitigating key factors that generate unnecessary processing demands (e.g., Mayer & Moreno, 2003). Specifically, educators strive to design materials in which comprehension processes are directed toward key content rather than extraneous details or interfaces. For example, presentations can be segmented such that information is presented in brief chunks with learner-controlled pacing (segmentation principle). When learners are required to engage in deep comprehension processes, it can be beneficial to focus

*Correspondence to: Rod D. Roscoe, Human Systems Engineering, The Polytechnic School, Ira A. Fulton Schools of Engineering, Arizona State University, 7271 E. Sonoran Arroyo Mall, Santa Catalina, 150D, Mesa, AZ 85212, USA.
E-mail: rod.roscoe@asu.edu

their time and attention on individual ideas while they gradually develop their understanding. Similarly, instructional designers can eliminate superfluous material that only serves to distract the learners (coherence principle), and can use cues (e.g., agent gestures) to guide attention to key concepts (signaling principle). Visual and verbal materials should also be aligned in terms of their placement onscreen and temporal presentation. Essential text, images, and narrations should appear near each other in the presentation (spatial contiguity principle), and corresponding text and narrations should occur simultaneously rather than sequentially (temporal contiguity principle).

In this study, we focus upon the *redundancy principle* (e.g., Mayer & Johnson, 2008) for the design of instructional materials in a writing strategies tutoring system. Verbally redundant presentations can occur when a narrator verbalizes a caption that appears beneath a diagram or when an animated agent 'reads aloud' examples or text that are simultaneously presented onscreen. Prior research has observed mixed or negative findings when fully redundant (i.e., identical) information is presented simultaneously via text and narration (e.g., Adesope & Nesbit, 2012; Jamet & Le Bohec, 2007; Kalyuga, Chandler, & Sweller, 1999; Moreno & Mayer, 2002). On one hand, if the visual and auditory channels are separate, then identical stimuli in each channel might not interfere with each other. One might even expect a positive effect if processing in one channel supported processing in the other. For instance, learners with reading difficulties may stumble over unfamiliar words seen in the text, but hearing those words spoken aloud may offer additional cues for decoding and comprehension (Scheiter, Schuler, Gerjets, Huk, & Hesse, 2014). By contrast, redundant materials also place higher demands on two processing channels, but each stream of information is the same. Nothing new is gained by attending to and trying to reconcile both channels, and doing so merely places additional, unnecessary load on the learner. These problems may be exacerbated by presentations that also violate other principles, such as spatial contiguity and coherence (Mayer & Johnson, 2008).

In a recent meta-analysis, Adesope and Nesbit (2012) considered the mixed findings regarding multimedia learning with redundant text and narration. They observed that verbally redundant materials were not more effective than text-only presentations (weighted mean effect size, $g+ = -.04$) although they were they were somewhat more effective than narration-only presentations ($g+ = .29$). Thus, when students were given textual information and explanations, the addition of redundant narration was of little use. However, students may have found narration-only presentations challenging because of inherent limitations of auditory channel processing. Importantly, the majority of studies reviewed by Adesope and Nesbit (2012) examined highly redundant text–narration presentations in which information presented in the text and narration were identical or verbatim. Few studies considered *partially redundant* presentations with a lower degree of correspondence between text and narration although these studies showed strong effects overall ($g+ = .99$).

Mayer and Johnson (2008) argued that fully redundant presentations violate the coherence principle, which states that extraneous details should be omitted from multimedia materials. In this case, offering text that merely reproduces the narration is unnecessary. Instead, redundant text may be used more sparingly to only highlight key terms, phrases, and explanations that are especially important (e.g., a signaling function). In two experiments, Mayer and Johnson (2008) observed that partially redundant text used in this manner resulted in significantly stronger learning outcomes than nonredundant presentations. More recently, Yue and colleagues (Yue, Bjork, & Bjork, 2013) contrasted three levels of verbal redundancy: no redundancy (narration only), partial redundancy (text summaries of the narration; partial overlap), and full redundancy (identical text and narration; ~100% overlap). Their results demonstrated that both no redundancy and full redundancy resulted in poorer learning than partial redundancy. That is, when the text was only partially overlapping with the narration, learning outcomes were stronger than when the text and narration were either mismatched or perfectly overlapping. Ari and colleagues (2014) similarly found that partially redundant materials could be beneficial in self-paced learning of complex content.

An important aim of the current study is to further clarify guidance for the design of multimedia instructional materials. In this study, we experimentally manipulate the *degree of redundancy* for presentations with lower text–narration correspondence. Specifically, instead of broad contrasts of no redundancy versus partial redundancy or perfect redundancy, this study examines three different levels of partial redundancy. Although evidence suggests that partial redundancy is ideal, we wish to better understand the effective range of this phenomenon. Should partially redundant presentations have a small degree of text–narration overlap (e.g., 10% overlap) or should the overlap be greater (e.g., 50%)? How worried should instructional designers be about the amount of overlap? Yue and colleagues (Yue et al., 2013) argued that partial redundancy could create 'desirable difficulty' such that mild discrepancies between text and narration stimulate or facilitate active comprehension processes of generation and integration across modalities. Similarly, partial redundancy may help to signal key ideas and direct attention (Mayer & Johnson, 2008). A crucial question is whether the degree of overlap influences such desirable difficulty or signaling and at what point (i.e., too much or too little overlap) the benefits may not be observed.

An additional factor to consider in relation to the degree of redundancy may be learners' prior reading ability (e.g., McNamara & Shapiro, 2005; Scheiter et al., 2014), which includes reading comprehension and vocabulary skills. When nonredundant information is presented via text and narration, learners must engage in comprehension processes to understand and integrate the two channels. Under normal circumstances, characteristics of the readers (e.g., reading ability) and text (e.g., cohesion) can interact to determine how well readers integrate information and build a coherent representation (McNamara, Kintsch, Songer, & Kintsch, 1996; McNamara & Magliano, 2009; O'Reilly & McNamara, 2007; Ozuru et al., 2009). Skilled readers, for example, build deeper understanding of texts by more regularly engaging in active processing (e.g., generating inferences) than less

skilled readers (Oakhill, Cain, & Bryant, 2003; Rapp, van den Broek, McMaster, Kendeou, & Espin, 2007). Presentations that include text and narration yield benefits when learners engage in active processing and integrate the two modalities together, suggesting more-skilled readers may be better equipped to comprehend multimedia presentations. This may be true particularly when visual and auditory channels are related but not redundant.

Less-skilled readers, however, may benefit from relatively more redundancy between information presented through each modality. Adesope and Nesbit (2012) observed benefits of verbally redundant presentations (compared to narration-only) for students fluent in the language of instruction ($g+=.24$), early or nonfluent ($g+=0.82$), or second-language learners ($g+=.58$). Although only a very small number of studies examined the latter two cases, effect sizes suggested that less fluent readers benefit more from full redundancy. More directly, Scheiter et al. (2014) tested the potential moderating effects of reading comprehension skill when learning from presentations that were text-only or text with animations, and between presentations that were written-only, narration-only, or (verbally redundant) written-with-narration. Their results demonstrated a positive effect of the multimedia instructional materials (text and animation) for immediate recall, and they also observed that verbally redundant materials hindered learning compared with narration-only presentations. Importantly, although students of higher reading ability outperformed students of lower reading ability, reading skills did not interact with multimedia or modality variables. Thus, in a direct test, prior reading ability did not appear to moderate the effects of verbal redundancy.

One limitation of prior work is that reading ability and verbal redundancy were only considered in cases of high text–narration overlap. The relative effects of partially redundant materials, and how such presentations benefit more and less-skilled readers, remain an open question. Intuitively, more-skilled readers may be better equipped to take advantage of the signaling functions of partially redundant materials and to engage in deep integration processes to reconcile text and narration channels. Thus, these learners might be equally successful with minimally redundant (e.g., 10% overlap) to moderately redundant (e.g., 50% overlap) presentations. More-skilled readers might even benefit most from relatively lower correspondence because such conditions require the most active selecting and integrating processes. In contrast, less-skilled readers, who struggle with selection and integration processes in even single modality materials (e.g., text, McNamara & Magliano, 2009; McNamara & Shapiro, 2005), may find it more challenging to understand presentations with very low overlap (e.g., 10% overlap). Although these students may still benefit from partially redundant materials that stimulate more active processing, a higher correspondence (e.g., 50% overlap) between the text and narration may be more suitable.

WRITING PAL

The current study occurs within the context of W-Pal, an ITS developed to support adolescent students' acquisition of writing strategies across three phases of the writing process (Roscoe, Brandon, Snow, & McNamara, 2013; Roscoe & McNamara, 2013; Roscoe, Varner, Weston, Crossley, & McNamara, 2014). The system comprises eight instructional modules that offer explicit strategies for prewriting (*Free-writing* and *Planning*), drafting (*Introduction Building*, *Body Building*, and *Conclusion Building*), and revising (*Paraphrasing*, *Cohesion Building*, and *Revising*). Students are introduced to writing strategies and mnemonic devices via short, animated videos narrated by pedagogical agents. W-Pal allows students to practice these strategies in two complementary ways. First, students can practice targeted strategies by playing a suite of educational games. Each module is associated with one or more games that allow students to practice identifying examples of strategy use or applying the strategies to author new text. Second, students can practice by writing prompt-based, argument essays similar to the SAT exam. Students submit their essay to the W-Pal system, which provides summative feedback (i.e., a holistic rating) and formative feedback (i.e., actionable recommendations for strategies and ways to revise the text). Such scores and feedback are driven by natural language processing algorithms that assess numerous linguistic features and properties of the text (McNamara, Crossley, & Roscoe, 2013). Prior research has found that interacting with the complete W-Pal system over a period of 2 to 3 weeks supports improved writing proficiency, writing strategy acquisition, substantive revising, and self-efficacy (e.g., Crossley, Varner, Roscoe, & McNamara, 2013; Roscoe, Brandon, et al., 2013; Roscoe, Snow, & McNamara, 2013).

With regards to multimedia learning, a key issue pertains to the design of the instructional lesson videos and accompanying agent narration. W-Pal videos are generally well aligned with Mayer's (2005, 2009) design principles. For instance, the lessons are segmented and self-paced, and related visual and verbal materials are both spatially and temporally contiguous. Prior feasibility testing quickly revealed the importance of removing extraneous details—student users responded negatively to humorous asides and off-topic banter between animated agents and demanded more concise, content-focused narration. However, although W-Pal lesson videos were designed to provide partially redundant text and narration, the 'ideal' degree of overlap remained unclear. To provide writing strategy instruction that is effective and accessible to a broad range of adolescents (e.g., students of different reading ability levels), it was important to understand whether the lessons may need to be redesigned to offer more or less redundancy.

This context for investigating partial redundancy diverges in meaningful ways from commonplace features of prior work. First, previous research has primarily focused on well-defined domains such as lightning and mechanical systems (e.g., Mayer & Johnson, 2008) and astronomy (e.g., Yue et al., 2013), and the instructional materials typically require about 5 minutes to view the complete presentation. Second, previous work has overwhelmingly analyzed college undergraduate participants (Adesope & Nesbit, 2012) learning in controlled (e.g., laboratory) environments. In contrast, W-Pal targets high school adolescents and addresses the ill-defined domain of writing. The

characteristics of effective writing are often difficult to assess and individual authors may employ diverse strategies. Thus, when learning about writing and writing strategies, students must often grapple with problems (e.g., lack of cohesion) that involve multiple or subjective solutions. In addition, although individual W-Pal lesson videos are about 5 minutes in length, each strategy module (e.g., Cohesion Building) comprises four to five videos. Consequently, instruction on a given topic in W-Pal requires about 20 to 25 minutes of viewing. Overall, the current research context represents an interesting departure from previous work that explores partial redundancy by targeting a younger population, a novel learning domain, and longer instructional materials.

Research questions

Prior research has observed that partial redundancy between text and narration in multimedia presentations may be more beneficial than highly redundant (i.e., the redundancy effect) or single media presentations (i.e., the multimedia effect). Within the context of partially redundant presentations, this study explores how the degree of text–narration overlap, along with prior reading ability, may impact learning. Four questions thus guide our research and analyses:

- Do adolescent students improve their knowledge of writing by studying animated lessons (i.e., partially redundant multimedia presentations) provided by W-Pal?
- Are knowledge gains influenced by the degree of redundancy?
- Are knowledge gains influenced by prior reading ability?
- How do degrees of redundancy and prior reading ability interact to influence learning?

METHOD

Participants

Participants included 90 high school students (grades 9 through 12; primarily the 10th grade) from an urban area in the southwestern USA. The students were recruited via their English classroom teachers and were offered extra credit for their time. Participants were asked to provide their gender, age, ethnicity, year in school, and self-reported GPA. There were no significant differences in the distribution of demographic factors across conditions (i.e., p-values for all F or X^2 tests were $>.30$). Demographic data are summarized in Table 1.

Table 1. Gender, ethnicity, year in school, and GPA of participants by redundancy condition

	Partial redundancy condition		
Measure	10% overlap ($n = 32$)	26% overlap ($n = 28$)	50% overlap ($n = 29$)
Gender			
Female	14	16	16
Male	18	13	13
Age[a]	15.3 (0.8)	15.3 (1.0)	15.2 (0.7)
Ethnicity			
African-American	5	5	2
Asian	5	2	1
Caucasian	18	13	17
Hispanic	3	7	5
Year in school			
Freshman	5	6	3
Sophomore	22	17	22
Junior	4	5	3
Senior	1	1	1
GPA range			
1.6–2.0	2	0	2
2.1–2.5	1	2	3
2.6–3.0	7	5	3
3.1–3.5	6	12	9
3.6 and above	16	10	12
Reading score[a]	−.06 (1.88)	−.50 (1.61)	.57 (1.89)

Note. [a]Values reported for age and reading score are means. All other values are frequency counts.

Learning domain

Students learned about strategies for making their writing more cohesive via lessons from the W-Pal Cohesion Building module. This module includes four strategy lesson videos. In the *Cohesion Building Overview* lesson, an animated agent (Mr. Evans, a classroom teacher character) provides an overview of cohesion, offering a simplified definition of cohesion and its role in writing quality. For example, Mr. Evans discusses how cohesion involves building connections between ideas such that ideas 'flow' from sentence to sentence and from paragraph to paragraph. Students are taught that cohesion generally results in a more coherent, unified, and understandable essay. Mr. Evans then introduces three cohesion building strategies that are further explained in subsequent lessons. The strategy-specific lessons are narrated by one of two high school student characters, Sheila or Mike. In the *Signpost Strategy* lesson, students are taught to identify and address undefined referents (e.g., words such as *this* and *some* that are not specified by a noun phrase). In the *Connectives Strategy* lesson, students learn how to use transition words and phrases (e.g., *moreover* and *on the other hand*) to show conceptual connections between sentences and ideas. Finally, students are shown how to selectively repeat key themes and words through a text in the *Threading Strategy* lesson. Each lesson video is at most 5 minutes in duration, totaling about 20 minutes of instruction.

Conditions

Participants were randomly assigned to one of three conditions that varied by percentage of text–narration redundancy. Across all conditions, the lesson video background, animated agents, narration scripts, and duration were held constant. All text appeared on a whiteboard that was depicted next to the agent, and the location and size of the whiteboard remained constant. Information content was equivalent across conditions, but the wording of the onscreen text varied experimentally (Figure 1). Partial redundancy was manipulated not by changing the quantity of text included onscreen but by manipulating the degree of overlap. Specifically, the

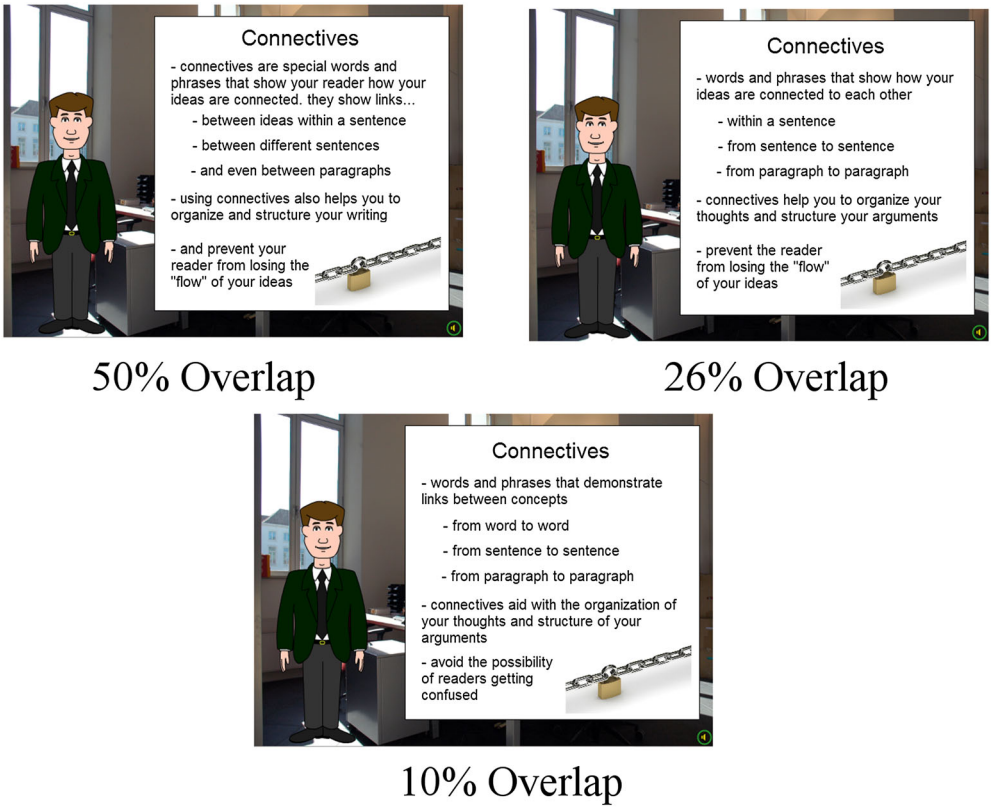

Figure 1. Lesson presentations maintained content equivalence and similar visual organization across 50%, 26%, and 10% overlap conditions

50% overlap condition ($n = 29$) was presented with a whiteboard with text that was verbally delivered by the character. Not everything the character said was on the whiteboard, but every word on the whiteboard was said by the character (approximately one out of every two words). The 26% overlap condition ($n = 29$) was presented with a whiteboard that summarized lesson strategies and highlighted key terms, with about one of every four words overlapping. The 10% overlap condition ($n = 32$) viewed a whiteboard on which most content words were different from the narration. The text explained the same information using different words and sentence structure than the narration, resulting in about 1 out of every 10 words overlapping between the script and onscreen text. Importantly, the overall amount of text onscreen remained similar across conditions (refer to Figure 1 for an example).

Although these conditions represent more nuanced variations in redundancy than are typically examined (e.g., perfectly overlapping multimedia materials versus non-overlapping or single modality materials), the differences across conditions were still substantive. In the 50% overlap condition, one out of every two words overlapped between the narration script and the onscreen text. In the 10% overlap condition, such overlap only occurred for 1 out of every 10 words. Moreover, these variations also span commonplace and authentic design of multimedia materials. In practice, reproduction of an agent's entire script onscreen (100% overlap) would be cumbersome and inauthentic. Self-pacing and learner control are hindered when agents read text aloud to learners, and the coherence principle is violated when the visual interface is cluttered by unnecessary words and images. Similarly, a lack of any supporting text or a complete mismatch between text and narration (0% overlap) would also be inauthentic compared with multimedia learning materials used in practice (Mayer, 2005; Mayer, 2009). In light of these concerns, along with the logistics of conducting classroom-based research with high school students, we did not include 0% overlap and 100% overlap conditions in this study.

Overlap percentages

To establish the degree of overlap between the whiteboard text and character narration, we tabulated the number of words that appeared on the whiteboard and *matched* the narration. If the text and narration used different forms of the same word (e.g., 'easier to *understand*' versus 'more *understandable*'), the match was counted as one-half. Likewise, a match was counted as one-half if the word appeared in both the text and narration, but within a different segment of the sentence or different syntax. For example, in one case, the agent stated, 'These *words* are like *signposts* that point at important ideas', while the whiteboard displayed, 'link all "*signpost*" *words* to a meaningful noun or noun phrase'. The overlapping terms here were 'words' and 'signpost'. However, because they are rearranged in the sentence, each was counted as a half-match. Non-content words, such as *a*, *an*, *the*, and, *but*, were included in the calculation. To obtain the overall degree of overlap, we divided the total count of matching terms by the total number of words in the narration script. Importantly, the amount of onscreen text was largely similar across conditions, and there were consistently fewer words on screen than in the narration. That is, in contrast to prior studies where 'high overlap' included longer verbal labels whereas 'low overlap' relied upon short verbal

labels, our conditions maintained a similar amount of text and visual organization.

Time on task

Participants in all conditions completed the same procedures, and the experimental manipulations did not affect the length of the lesson videos. Nonetheless, as with many naturalistic and authentic learning tasks, procedures were self-paced and participants could potentially adjust the amount of time spent studying the lessons based on the amount of redundancy (e.g., Ari et al., 2014). For example, learners might respond to low overlap by taking more time to consider the dual streams of information. Self-pacing effects were not observed in this study. Across conditions, participants appeared to spend an average of just over an hour completing their assigned tasks (i.e., 74 minutes in the 50% overlap condition, 69 minutes in the 26% overlap condition, and 75 minutes in the 10% overlap condition). These minor differences in time-on-task were not statistically significant, $F < 1.00$.

Measures

Gates–MacGinitie reading test

Reading comprehension skill was tested with the Gates–MacGinitie (4th ed.) reading skill test (form S) level 10/12 (MacGinitie & MacGinitie, 1989). The test consisted of 48 multiple-choice questions assessing students' comprehension of 11 short passages. Each passage was associated with two to six questions, which measured shallow comprehension as well as deeper comprehension that required the reader to make inferences about the text. The participants were administered the standard instructions with 20 minutes to complete the test. The vocabulary section of the Gates–MacGinitie (4th ed.) test (form S) level 10/12 (MacGinitie & MacGinitie, 1989) was used to assess vocabulary skill. The test comprised 45 sentences or phrases, each with an underlined vocabulary word. For each underlined word, participants were asked to select the most closely related word from a list of five choices. The items were designed to suggest the word's part of speech but provide no contextual information about meaning. Participants were administered the standard instructions and given 10 minutes to complete the test. An examination of raw mean vocabulary scores ($M = 28.6$, $SD = 8.4$) suggested that students' vocabulary skills were fairly strong (i.e., a score range of approximately 20–25 is indicative of a grade equivalency range of 9–12). By contrast, raw mean comprehension scores ($M = 22.9$, $SD = 9.9$) suggested that students' comprehension skills were at or slightly below grade level (i.e., a score range of approximately 22–30 is indicative of a grade equivalency range of 9–12). Overall, participants demonstrated a range of reading skill comparable with normal high school performance, but with good vocabulary knowledge.

For purposes of analysis, students' scores on each subscale were transformed into standard deviation units and summed, thus producing a single score representing overall reading ability (Table 1). A one-way ANOVA comparing reading scores across all conditions was not statistically significant, $F(2,87) = 2.61$, $p = .079$. However, pairwise comparisons suggested that, despite random assignment, students in the 26% overlap condition had lower prior reading ability than did students in the 50% overlap condition ($p = .026$).

Strategy knowledge test

Students answered three open-ended questions assessing their knowledge and understanding of cohesion and cohesion-building strategies. Question 1 asked, 'Cohesion is an important aspect of writing. In your own words, please give a definition of cohesion.' Question 2 probed students' understanding of the impact of cohesion, 'How does cohesion influence the quality of an essay?' Finally, Question 3 directly addressed strategy knowledge, 'What strategies can be used to improve the cohesion of an essay?' Students answered these questions both before and after instruction. Importantly, these questions did not simply test recall or recognition of the video contents, but instead tapped specific knowledge and comprehension about cohesion in writing.

To score students' responses, the researchers first reviewed the instructional videos (i.e., agent narrations along with onscreen text and illustrations) to extract key idea units pertaining to each question. For example, with regards to the definition of cohesion, the materials explained that cohesion is the linking or bridging of ideas, across sentences and paragraphs, which results in unified themes and arguments. Using these idea units as a template, we reviewed students' responses to understand how students expressed these ideas in their own words. For instance, students might not use terms like 'linking' or 'bridging,' but instead describe 'joining two ideas smoothly' or 'how all the sentences relate or tie together'. Because students' responses to any of the questions could potentially address definitions, impact, or strategies (e.g., explaining how cohesion influences essay quality while also describing a cohesion-building strategy), all three responses were reviewed together for scoring purposes. Students could receive credit for any given idea unit only once, even if that idea was stated in multiple question responses.

The coding scheme was iteratively tested and refined. Two of the researchers independently coded an initial set of 19 student responses and then discussed and resolved discrepancies. This process was repeated with a different set of 16 student responses. A final set of 16 students' responses were then independently coded and assessed for inter-rater reliability. Overall, the coders agreed on 96.6% of the codes, yielding a Kappa of 0.91. We determined that this was an acceptable agreement and a single coder finished the remaining responses. The final coding scheme included template responses along with exemplars of acceptable alternative expressions (Table 2). Students could earn up to 2 points for defining cohesion, 4 points for describing the influence of cohesion on writing quality, and 4 points for describing strategies for building cohesion (i.e., maximum total score of 10).

Procedure

Participants completed the entire study, including instruction and assessments, via their home computers. The study was completed in a single session using a web-based survey service. Each participant completed one of three surveys. Each survey began with the same pretest questions. Next, students watched the lesson videos, which varied based on text–narration overlap (i.e., 10%, 26%, or 50% overlap).

Table 2. Template and exemplars for coding student responses to knowledge questions

Idea units	Description and examples of idea units
Definition of cohesion	
Linking of ideas	Ideas are connected across sentences and paragraphs 'Cohesion is the connection between sentences' 'it's how you connect ideas between sentences and paragraphs'
Unity	Ideas and themes are unified across the whole text 'Cohesion if making parts of your writing come together as a united whole.' 'It's a form of unity within a piece of literature.'
Impact on quality	
Flow	Smooth flow from one idea to the next 'Flowing smooth' 'Being able to make ideas flow'
Readability	Text can be read easily by the reader 'A cohesive paper is easy to read' 'clearly written'
Understandability	Main ideas can be understood by the reader 'makes your essay make more sense' 'It makes it easy to understand'
On-topic	Ideas seem related to one another without tangents or digressions 'Keeps an essay strong by being on topic.' 'Cohesion is the binding topic of an essay, instead of going of tangent'
Cohesion strategies	
Connectives	Use of transition words and phrases to link ideas 'Connectors can be used to improve cohesion.' 'For example, poeple should what my class calls "transition words"'
Signpost	Defining referents (e.g., 'this'); avoiding vague terms and phrases 'Clarifying "signposts"' 'Look for words such as "that, this most" explain what those things are'
Threading	Repeating key terms and ideas across sentences and paragraphs 'Referring back to or building on top of a previous sentence' 'Threading strategy—"sew" the words together'
Other	Other strategies that improve cohesion indirectly (e.g., outlining) 'Planning also helps you write a cohesive essay as well.' 'Reading a paper out loud for flow'

Finally, participants completed the posttest questions. On average, the study required just over 1 hour to complete.

RESULTS

Overall learning gains

An initial analysis simply examined overall student learning across all conditions. A one-way, repeated-measures ANOVA was conducted to determine whether students' knowledge of cohesion improved from pretest to posttest (i.e., an effect of instruction). As shown in Table 3, students increased significantly in their knowledge of cohesion from pretest ($M = 2.07$) to posttest ($M = 2.90$). It is important to note that these scores and gains are rather low relative to the maximum possible score; cohesion is a difficult concept to teach and understand at the high school level. Nonetheless, these gains are meaningful ($d = .54$) given that students received only 20 minutes of instruction without the opportunity to practice the strategies in their own writing.

Table 3. Mean pretest and posttest knowledge assessment scores

	Pretest		Posttest				
Measure	Mean	SD	Mean	SD	F	p	d
Total score	2.07	1.26	2.90	1.76	28.60	<.001	.54
Definition of cohesion	0.27	0.49	0.32	0.54	<1.00	.339	.11
Impact on quality	1.22	0.88	1.53	0.97	7.51	.007	.33
Cohesion strategies	0.58	0.56	1.04	0.95	24.09	<.001	.60

Subsequently, we sought to tease apart students' understanding of cohesion related to their definition of cohesion, knowledge of the role cohesion plays in writing quality, and cohesion-building strategies. We found that students generally struggled to define cohesion at pretest ($M = .27$) and posttest ($M = .49$) and did not gain significantly. However, students did appear to gain knowledge about the impact of cohesion on writing quality from pretest ($M = 1.22$) to posttest ($M = 1.53$) and cohesion-building strategies from pretest ($M = .58$) to pretest ($M = 1.04$). W-Pal's primary focus is to provide students with actionable strategies that they can implement to improve their writing. Thus, these results suggest that W-Pal was somewhat successful in communicating such information to students. Nonetheless, future iterations of W-Pal might provide further elaboration to better explain the fundamental nature of cohesion.

Influence of degree of overlap and prior reading ability

The effects of the degree of overlap and prior reading ability were first tested via a 2 (instruction) × 3 (degree of overlap)

mixed, repeated-measures ANCOVA. Instruction was a within-subjects variable (pretest vs. posttest), and degree of redundancy was a between-subjects variable (50% vs. 26% vs. 10% overlap). Prior reading ability was included as a covariate. To further test for a potential three-way interaction among the three variables, a follow-up analysis used a median split to divide students into 'higher prior reading ability' and 'lower prior reading ability' groups. Subsequently, a 2 (instruction) × 3 (degree of overlap) × 2 (reading ability) mixed-repeated measures ANOVA was conducted. For clarity, Tables 4–6 display only means and standard deviations based on these follow-up analyses. Because of the observed differences across knowledge types, analyses of redundancy and reading ability were conducted separately for each knowledge type.

Learning about the definition of cohesion

For students' ability to define the concept of cohesion, we observed an effect of prior reading ability, $F(1,86) = 10.28$, $p = .002$, but observed no main effects of instruction or degree of overlap (both $Fs < 1.00$). Thus, as noted earlier, students overall did not improve in their knowledge of the definition of cohesion. In addition, students struggled with this concept regardless of the degree of overlap in the multimedia presentation. However, students with stronger reading ability demonstrated a better grasp of the basic nature of cohesion. No significant interactions were observed in either the initial or follow-up analysis (Table 4).

Learning about the impact of cohesion

For students' knowledge of how cohesion impacts writing quality, significant main effects were observed for instruction, $F(1,86) = 7.45$, $p = .008$, and prior reading ability, $F(1,86) = 17.04$, $p < .001$, but no main effect was observed for degree of overlap ($F < 1$). No significant interactions were observed in either the initial or follow-up analyses (Table 5). Thus, students in this study appeared to acquire knowledge about how cohesion influences the quality of an essay, but such gains did not vary as a function of either partial redundancy or prior reading ability. Similar to findings for definitions of cohesion, students who possessed stronger reading skills also demonstrated better overall knowledge about the impact of cohesion.

Learning about cohesion-building strategies

For students' knowledge of strategies for making their writing more cohesive, we observed significant main effects for instruction, $F(1,86) = 24.80$, $p < .001$, and prior reading ability, $F(1,86) = 19.65$, $p < .001$, but observed no main effect of degree of overlap ($F < 1$) (Table 6). Interestingly, a significant interaction was observed in the initial analysis between learning gains and prior reading ability, $F(1,86) = 5.24$, $p = .024$. These effects were further examined in the follow-up analysis. Although students with lower reading ability gained from pretest ($M = .42$, $SD = .50$) to posttest ($M = .71$, $SD = .82$), students with higher reading ability appeared to learn somewhat more about cohesion strategies

Table 4. Mean pretest and posttest scores for definition of cohesion as a function of degree of overlap and prior reading ability median split

Degree of overlap	Pretest				Posttest			
	Lower prior reading ability		Higher prior reading ability		Lower prior reading ability		Higher prior reading ability	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
50%	.07	.27	.47	.64	.14	.36	.73	.80
26%	.12	.34	.31	.48	.13	.35	.31	.48
10%	.27	.46	.35	.61	.12	.34	.47	.51

Table 5. Mean pretest and posttest scores for impact of cohesion as a function of degree of overlap and prior reading ability median split

Degree of overlap	Pretest				Posttest			
	Lower prior reading ability		Higher prior reading ability		Lower prior reading ability		Higher prior reading ability	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
50%	.64	.74	1.67	.72	1.57	.85	1.73	.96
26%	1.25	.86	1.31	.75	1.00	.89	1.70	1.05
10%	.67	.98	1.70	.68	1.33	1.11	1.92	.76

Table 6. Mean pretest and posttest scores for cohesion strategies as a function of degree of overlap and prior reading ability median split

Degree of overlap	Pretest				Posttest			
	Lower prior reading ability		Higher prior reading ability		Lower prior reading ability		Higher prior reading ability	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
50%	.57	.51	1.00	.53	.78	.80	1.47	.83
26%	.31	.48	.69	.48	.62	.72	1.00	.91
10%	.40	.51	.53	.62	.73	.96	1.59	1.06

from pretest ($M = .73$, $SD = .58$) to posttest ($M = 1.38$, $SD = .96$). The interaction was marginally significant, $F(1,86) = 3.60$, $p = .061$. No other two-way or three-way interactions were found.

DISCUSSION

Multimedia instructional materials must be carefully designed to engage students in active comprehension processes that are focused upon important content (Mayer, 2005, 2009). Within this framework, high levels of verbal redundancy—the extent to which visual materials (e.g., text and diagrams) and auditory materials (e.g., narration and sound effects) are closely overlapping in content—have been shown to hinder learning (e.g., Jamet & Le Bohec, 2007; Leahy et al., 2003; Moreno & Mayer, 2002). When the exact same information is presented in both visual and auditory channels, learners may be forced to waste cognitive resources attempting to process two identical streams for little benefit. By contrast, partially redundant presentations are those in which verbal redundancy is used purposefully to signal key terms and concepts. That is, core ideas and explanations presented in the narration might be reinforced using redundant text on screen (e.g., a summary), whereas less important points or details might be omitted from the text. Studies of partial redundancy have found that such presentations lead to stronger learning gains than either nonredundant or fully redundant presentations (Mayer & Johnson, 2008; Yue et al., 2013). Partially redundant materials may facilitate learners' active selection, organization, and integration of ideas by marking where and when students need to pay attention while providing just enough discrepancy to stimulate integration across modalities.

In this study, we examined the effects of varying degrees of partial redundancy. Although prior research has established that partial redundancy can be beneficial, it was unclear whether variations in the amount of partial redundancy would impact learning. For example, how 'minimal' might the text–narration overlap be and still benefit learners? In addition, we considered whether an 'optimal' degree of partial redundancy might differ on the basis of students' prior reading ability. Various levels of redundancy may not be suitable to all learners. For instance, although more-skilled readers might benefit from low overlap that fosters integration across modalities, less-skilled readers might only experience these benefits with a bit more signaling (i.e., more redundancy). Past research has suggested that students of all reading abilities levels can learn from multimedia presentations (Adesope & Nesbit, 2012) but reading ability may not moderate the effects of redundancy (Scheiter et al., 2014).

Our results suggest that variations in the degree of partial redundancy do not significantly influence learning gains. Across all three levels of partial verbal redundancy (i.e., 10%, 26%, and 50% overlap), students improved significantly in their ability to describe the impact of cohesion on text quality and specific strategies for building cohesion. One possible explanation is that the manipulation was too fine-grained. Perhaps the variations in verbal redundancy were too subtle to have a meaningful impact. In practice, however, differences across our experimental conditions were not subtle (Figure 1). In one condition, the overlap between text and narration was 1 out of every 10 words (10%), whereas other conditions demonstrated overlap of one out of every four words (26%) or one out of every two words (50%). These are substantive variations. In some ways, this is a promising finding because it means that a broad range of partially redundant presentations may be useful for multimedia instruction. ITS developers and instructional designers may not need to worry about finding a 'perfect' level of overlap but may instead focus on providing the right content, the best scaffolds, and other design principles (e.g., coherence and relevance). Nonetheless, a potential contrast for future research may be to examine a larger disparity between partially redundant materials (e.g., 80% overlap versus 20% overlap). Additional fine-grained manipulations may also be useful in determining optimal presentation format, such as explicitly varying both sentence format (key words or complete sentences) and type of redundancy (exactly matching words or using synonyms).

Also in accord with prior research, we observed a strong effect of prior reading ability, such that more-skilled readers possessed significantly more knowledge about cohesion than less-skilled readers. Reading skill is a complex phenomenon that comprises word-level knowledge and skills (e.g., recognizing words, decoding unfamiliar, and breadth of vocabulary) along with text-level knowledge and skills (e.g., understanding text structure and being able to bridge ideas across text sections) (e.g., Oakhill & Cain, 2012). The current study further highlights the differences between more-skilled and less-skilled readers with respect to their understanding of text flow and cohesion. At both pretest and posttest, more-skilled readers demonstrated more knowledge about cohesion. Thus, understanding of text cohesion may constitute one aspect of skilled readers' text expertise. Finally, in the case of strategy knowledge—the focus of W-Pal content and instruction—stronger reading ability also seemed to foster learning from the multimedia presentations. It is likely that students who already possessed some foundational knowledge about cohesion and reading were better prepared to extend such strategy knowledge to the domain of writing.

Current results also provide additional support for past findings that reading ability may not moderate the effects of verbal redundancy. There was no interaction between reading skill and learning with partially redundant presentations. Although more-skilled readers outperformed their less-skilled counterparts, both groups of students gained overall. This result suggests that strategy instruction using animated agents and multimedia presentations can benefit students of diverse reading levels. One possibility, as suggested earlier, is that the manipulation of redundancy was too subtle. Students' reading abilities may be more sensitive to a starker contrast between high and low text–narration overlap. However, within the range of partially redundant materials used in this study, reading ability did not seem to moderate the effects of text–narration cohesion. This finding again suggests that ITS developers and instructional designers have some flexibility when creating multimedia presentations. One important goal for ITS developers is to identify student characteristics that can usefully guide the delivery of instructional content. The current findings suggest that reading ability may have

limited use in personalizing these kinds of presentation formats for different students.

One note of caution of these results pertains to the range of students recruited for the study. The majority of participants were 'A' or 'B' average students (i.e., GPA greater than 3.0 on a 4.0 scale) and thus may have benefitted from stronger general knowledge or other academic skills. For example, although our less-skilled and more-skilled readers differed from each other significantly, both groups may have represented generally capable readers. Inspection of the raw Gates–MacGinitie scores, however, suggested that students were well within the normal range of high school students for reading comprehension but had good vocabulary knowledge. In continued research, it may important to specifically sample from more diverse populations with a wider range of ability, including struggling readers, second-language learners, or readers with learning disabilities. Just as future research may need to examine a broader disparity between degrees of text–narration redundancy, this work may also need to consider a broader range of academic skills or other potential learning challenges.

Another contribution of this work relates to the W-Pal tutoring system, which specifically emphasizes writing strategy instruction and knowledge. These data provide additional evidence that W-Pal can support writing strategy knowledge acquisition (Roscoe, Brandon, et al., 2013). Although students received only a limited portion of what W-Pal offers—students in this study viewed only the lessons without opportunities to play strategy practice games or author practice essays—they were able to gain knowledge about cohesion. These gains might have been stronger in the context of additional practice and feedback with the complete system. Additionally, W-Pal currently provides only a brief introduction on the nature of cohesion, which students struggled to articulate both before and after instruction. Thus, one improvement to the system may be to offer more explicit instruction about the underlying principles of cohesion.

A final contribution speaks to the instructional domain and target population. Whereas the majority of past work on verbal redundancy and multimedia presentations has been at the post-secondary level (Adesope & Nesbit, 2012), the current study targeted high school aged adolescents. Our findings suggest that partially redundant multimedia materials are beneficial for younger learners. Similarly, although a handful of multimedia studies have targeted reading (e.g., Diao & Sweller, 2007), the large majority have addressed science and technical domains such as computer literacy (Craig et al., 2004), anatomy (Ari et al., 2014), astronomy (Yue et al., 2013), and meteorology (e.g., Moreno & Mayer, 2002). In contrast to well-defined learning domains, wherein key concepts and procedures are generally constrained or well-known, writing is an ill-defined learning domain. Writing assessment is often subjective and challenging, and diverse authors may employ distinct yet effective strategies. Indeed, recent research has observed that skilled writers may adopt very different approaches for composing high-quality essays (Crossley, Roscoe, & McNamara, 2014). Thus, the current work represents a valuable extension of research of multimedia learning into yet another important learning domain. The benefits of multimedia instructional materials do not only apply to college students studying well-defined domains.

ACKNOWLEDGEMENT

This research was supported by the Institute of Education Sciences, US Department of Education, through Grant R305A120707. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the IES.

REFERENCES

Adesope, O. O., & Nesbit, J. C. (2012). Verbal redundancy in multimedia learning environments: A meta-analysis. *Journal of Educational Psychology*, *104*, 250–263.

Ari, F., Flores, R., Inan, F. A., Cheon, J., Crooks, S. M., Paniukov, D., & Kurucay, M. (2014). The effects of verbally redundant information on student learning: An instance of reverse redundancy. *Computers & Education*, *76*, 199–204.

Chandler, P., & Sweller, J. (1991). Cognitive load theory and the format of instruction. *Cognition and Instruction*, *8*, 293–332.

Craig, S. D., Driscoll, D. M., & Gholson, B. (2004). Constructing knowledge from dialog in an intelligent tutoring system: Interactive learning, vicarious learning, and pedagogical agents. *Journal of Educational Multimedia and Hypermedia*, *13*, 163–183.

Craig, S. D., Gholson, B., & Driscoll, D. M. (2002). Animated pedagogical agents in multimedia educational environments: Effects of agent properties, picture features, and redundancy. *Journal of Educational Psychology*, *94*, 428–434.

Cramer, K. M., Collins, K. R., Snider, D., & Fawcett, G. (2007). The virtual lecture hall: Utilization, effectiveness, and student perceptions. *British Journal of Educational Technology*, *38*, 106–115.

Crossley, S. A., Roscoe, R. D., & McNamara, D. S. (2014). What is successful writing? An investigation into multiple ways writers can write successful essays. *Written Communication*, *31*, 184–214.

Crossley, S. A., Varner, L. K., Roscoe, R. D., McNamara, D. S. (2013). Using automated cohesion indices as a measure of writing growth in intelligent tutoring systems and automated essay writing systems. In K. Yacef et al. (Eds.), *Proceedings of the 16th International Conference on Artificial Intelligence in Education* (*AIED*) *Conference* (pp. 269–278). Heidelberg, Berlin: Springer.

Diao, Y., & Sweller, J. (2007). Redundancy in foreign language reading comprehension and instruction: Concurrent written and spoken presentations. *Learning and Instruction*, *17*, 78–88.

Eason, S. H., Goldberg, L. F., Young, K. M., Geist, M. C., & Cutting, L. E. (2012). Reader–text interactions: How differential text and question types influence cognitive skills needed for reading comprehension. *Journal of Educational Psychology*, *104*, 515–528.

Graesser, A. C., Lu, S., Jackson, G. T., Mitchell, H. H., Ventura, M., Olney, A., & Louwerse, M. M. (2004). AutoTutor: A tutor with dialogue in natural language. *Behavior Research Methods*, *36*, 180–192.

Jackson, G. T., & McNamara, D. S. (2013). Motivation and performance in a game-based intelligent tutoring system. *Journal of Educational Psychology*, *105*, 1036–1049.

Jamet, E., & Le Bohec, O. (2007). The effect of redundant text in multimedia instruction. *Contemporary Educational Psychology*, *32*, 588–598.

Johnson, W. L., Rickel, J. W., & Lester, J. C. (2000). Animated pedagogical agents: Face-to-face interaction in interactive learning environments. *International Journal of Artificial Intelligence in Education*, *11*, 47–78.

Kalyuga, S., Chandler, P., & Sweller, J. (1999). Managing split-attention and redundancy in multimedia instruction. *Applied Cognitive Psychology*, *13*, 351–371.

Lane, H. C., Hays, M. J., Core, M. G., & Auerbach, D. (2013). Learning intercultural communication skills with virtual humans: Feedback and fidelity. *Journal of Educational Psychology*, *105*, 1026–1035.

Leahy, W., Chandler, P., & Sweller, J. (2003). When auditory presentations should and should not be a component of multimedia instruction. *Applied Cognitive Psychology*, *17*, 401–418.

Leahy, W., & Sweller, J. (2011). Cognitive load theory, modality of presentation and the transient information effect. *Applied Cognitive Psychology*, *25*, 943–951.

MacGinitie, W. H., & MacGinitie, R. K. (1989). *Gates–MacGinitie Reading Tests* (3rd edn). Itasca, IL: Riverside.

Magliano, J. P., & Millis, K. K. (2003). Assessing reading skill with a think-aloud procedure and latent semantic analysis. *Cognition and Instruction*, *21*, 251–283.

Mayer, R. E. (Ed.) (2005). *The Cambridge handbook of multimedia learning*. New York, NY: Cambridge University Press.

Mayer, R. E. (2009). *Multimedia learning*. Cambridge University Press.

Mayer, R. E., & Johnson, C. I. (2008). Revising the redundancy principle in multimedia learning. *Journal of Educational Psychology*, *100*, 380–386.

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist*, *38*, 43–52.

McNamara, D. S., Crossley, S. A., & Roscoe, R. D. (2013). Natural language processing in an intelligent writing strategy tutoring system. *Behavior Research Methods*, *45*, 499–515.

McNamara, D. S., & Kintsch, W. (1996). Learning from texts: Effects of prior knowledge and text coherence. *Discourse Processes*, *22*, 247–288.

McNamara, D. S., Kintsch, E., Songer, N. B., & Kintsch, W. (1996). Are good texts always better? Interactions of text coherence, background knowledge, and levels of understanding in learning from text. *Cognition and Instruction*, *14*, 1–43.

McNamara, D. S., & Magliano, J. (2009). Towards a comprehensive model of comprehension. In B. Ross (Ed.), *The psychology of learning and motivation* (Vol. *51*, pp. 297–384). San Diego, CA: Academic Press.

McNamara, D. S., O'Reilly, T. P., Best, R. M., & Ozuru, Y. (2006). Improving adolescent students' reading comprehension with iSTART. *Journal of Educational Computing Research*, *34*, 147–171.

McNamara, D. S., & Shapiro, A. M. (2005). Multimedia and hypermedia solutions for promoting metacognitive engagement, coherence, and learning. *Journal of Educational Computing Research*, *33*, 1–29.

Moreno, R., & Mayer, R. E. (1999). Cognitive principles of multimedia learning: The role of modality and contiguity. *Journal of Educational Psychology*, *91*, 358–368.

Moreno, R., & Mayer, R. E. (2002). Verbal redundancy in multimedia learning: When reading helps listening. *Journal of Educational Psychology*, *94*, 156–163.

O'Reilly, T., & McNamara, D. S. (2007). Reversing the reverse cohesion effect: Good texts can be better for strategic, high-knowledge readers. *Discourse Processes*, *43*, 121–152.

Oakhill, J. V., & Cain, K. (2012). The precursors of reading ability in young readers: Evidence from a four-year longitudinal study. *Scientific Studies of Reading*, *16*, 91–121.

Oakhill, J. V., Cain, K., & Bryant, P. E. (2003). The dissociation of word reading and text comprehension. Evidence from component skills. *Language and Cognitive Processes*, *18*, 443–468.

Ozuru, Y., Dempsey, K., & McNamara, D. S. (2009). Prior knowledge, reading skill, and text cohesion in the comprehension of science texts. *Learning and Instruction*, *19*, 228–242.

Rapp, D. N., van den Broek, P., McMaster, K. L., Kendeou, P., & Espin, C. A. (2007). Higher-order comprehension processes in struggling readers: A perspective for research and intervention. *Scientific Studies of Reading*, *11*, 289–312.

Roscoe, R. D., Brandon, R. D., Snow, E. L., & McNamara, D. S. (2013). Game-based writing strategy practice with the Writing Pal. In K. Pytash & R. Ferdig (Eds.), *Exploring technology for writing and writing instruction* (pp. 1–20) Hershey, PA: IGI Global.

Roscoe, R. D., & McNamara, D. S. (2013). Writing Pal: Feasibility of an intelligent writing strategy tutor in the high school classroom. *Journal of Educational Psychology*, *105*, 1010–1025.

Roscoe, R. D., Snow, E. L., & McNamara, D. S. (2013). Feedback and revising in an intelligent tutoring system for writing strategies. In K. Yacef et al. (Eds.), *Proceedings of the 16th International Conference on Artificial Intelligence in Education* (*AIED*) (pp. 259–268). Heidelberg, Berlin: Springer.

Roscoe, R. D., Varner (Allen), L. K., Weston, J. L., Crossley, S. A., & McNamara, D. S. (2014). The Writing Pal Intelligent Tutoring System: Usability testing and development. *Computers and Composition*, *34*, 39–59.

Rowe, J. P., Shores, L. R., Mott, B. W., & Lester, J. C. (2011). Integrating learning, problem solving, and engagement in narrative-centered learning environments. *International Journal of Artificial Intelligence in Education*, *21*, 115–133.

Scheiter, K., Schuler, A., Gerjets, P., Huk, T., & Hesse, F. W. (2014). Extending multimedia research: how do prerequisite knowledge and reading comprehension affect learning from text and pictures. *Computers in Human Behavior*, *31*, 73–84.

Segedy, J. R., Kinnebrew, J. S., & Biswas, G. (2013). The effect of contextualized conversational feedback in a complex open-ended learning environment. *Educational Technology Research and Development*, *61*, 71–89.

Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive load theory*. New York: Springer.

Yue, C. L., Bjork, E. L., & Bjork, R. A. (2013). Reducing verbal redundancy in multimedia learning: An undesired desirable difficulty? *Journal of Educational Psychology*, *105*, 266–277.