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Strategies for comprehending and integrating texts and videos

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ABSTRACT

This study examines students' strategic processing when participants were asked to comprehend and integrate information presented via two texts or two videos. Evidence was found for strategies being both consistent (e.g., connecting content with prior knowledge) and distinct (e.g., vocabulary) across modalities of information presentation. No differences in comprehension and integration performance were identified across conditions, a variety of strategies (e.g., directing attention, connecting with prior knowledge) were associated with measures of both comprehension and integration. As this is among the first studies to compare strategies supporting video versus text integration, directions for future research are discussed.

Since its popularization in 2005, the video-sharing platform, YouTube, has come to play a disproportionately dominant role in U.S. culture and society. For instance, 57% of adolescents report using YouTube for purposes of both entertainment and learning (Lenhart, Madder, Smith, & MacGill, 2007) and 85% of teachers surveyed describe their students as somewhat or very likely to use YouTube when completing typical school assignments (Purcell, Heaps, Buchanan, & Friedrich, 2013).

Despite the prevalence of online video, both inside and outside of the classroom, research has not kept pace with understanding how students may process and learn from online video, as compared to learning from more traditional mediums, like text (Cennamo, 1993; Kay, 2012; Zhang, Zhou, Briggs, & Nunamaker, 2006). A particularly under-examined area of video processing has been investigating not only how individuals comprehend information from a single video, but also how students may integrate information from across multiple videos to learn about academic topics. The purpose of this study was to examine the strategies undergraduates used when asked to comprehend and integrate information presented via video versus via text.

1. Theoretical frame

This study is informed by theories that view comprehension as a meaning-making process (Kintsch, 1988, 1998). In a foundational model of comprehension, the Construction-Integration (CI) Framework, Kintsch and Van Dijk (1978) suggested that comprehension occurs through students' formation and connection of two cognitive models of text. First, the text-base model is a propositional model that closely mirrors the semantic structure of text (i.e., reflecting relations among propositional phrases). Second, the situation model integrates key content in text with students' prior knowledge, to form a representation of the central story in a passage. When the text-base and situation models are connected comprehension emerges.

Beyond comprehension, integration refers to the process of coming to understand a single topic or issue based on content presented across two or more information sources. Building on the CI model, Perfetti, Rouet, and Britt (1999), introduced the Documents Model (DM) to conceptualize students' integration of content across multiple texts. According to the DM, integration occurs when students construct two mental models of content presented across texts. The inter-text model maps the structural relations among texts. This includes mapping specific text content to document information about its origin (e.g., author, publisher) and representing the relations among texts, as agree, disagreeing, or complementing one another. The integrated mental model describes the common topic or issue discussed across texts, with key points emphasized and extraneous information excluded. When the inter-text and integrated mental models are combined, a documents model is formed.

In the documents model, the central issue, discussed across texts, is coherently understood while the contributions of individual texts to this coherent conceptualization are represented (Britt, Perfetti, Sandak, & Rouet, 1999, pp. 209–233). Although models by Kintsch and Van Dijk (1978) and by Perfetti et al. (1999) conceptualize comprehension and integration as occurring for sources that are primarily textual in nature, we can expect similar meaning-making mechanisms to function when students comprehend information presented through non-textual sources, for instance through video. Similarities in comprehension and integration may arise in students' processing of both text and video as video, like text, represents connected discourse, intended to relay a message. Moreover, in comprehending both text and video, students

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must form a single, coherent representation of information using their prior knowledge. Indeed, Magliano, Miller, and Zwaan (2001) found students' comprehension of narrative film to be similar to narrative text comprehension.

1.1. Strategies for comprehension

The text processing literature is replete with strategies considered to have a positive effect on comprehension (Alexander, Harris, & Graham, 1998; McNamara, 2004; Pressley & Afflerbach, 1995; Weinstein, Schulte, & Palmer, 1987). Afflerbach, Pearson, and Paris (2008) define strategies as "deliberate, goal-directed attempts to … construct meanings from text" (p. 368). Afflerbach and Cho (2009) introduced a taxonomy of reading strategies considered to be effective for single text comprehension. These strategies pertain to: (a) remembering important information, (b) monitoring comprehension, and (c) evaluating texts and content (Afflerbach & Cho, 2009; Pressley & Afflerbach, 1995). For instance, identifying a main idea or otherwise summarizing text is a strategy supporting the remembering of important information. Using context clues to identify the definition of an unfamiliar vocabulary term is a strategy associated with comprehension monitoring. Finally, considering an author's purposes for writing or judging the quality of author claims is an evaluation strategy.

McNamara (2004) identified an expanded set of strategies when examining undergraduates' reading of science texts on a variety of topics. Specifically, strategies identified included (a) comprehension monitoring, (b) paraphrasing, (c) engaging in bridging inferences (i.e., connecting content in text with previously read material), (d) elaboration (i.e., using prior knowledge to explain text content), (e) making predictions, and (f) using logic (i.e., using common sense or domain general knowledge to understand text content). However, among these, only strategies associated with the formation of bridging inferences and elaborations and the use of logic were associated with performance on a measure of text comprehension.

While both Afflerbach and Cho (2009) and McNamara (2004) adopted a taxonomical approach to examining students' strategy use during reading, Dinsmore and Alexander (2012, 2016) classified strategies more generally as reflecting surface- or deep-level processing. Surface-level processing is defined as the use of strategies to support the basic encoding of textual content. As a contrast, deep-level processing is defined as the engagement of strategies to manipulate or transform text content for learning. According to Dinsmore and Alexander (2012), strategies like rereading, skimming or skipping portions of text, and underlining constitute surface-level strategies, whereas questioning, arguing with text, or connecting content in text to prior knowledge or personal experience reflect deep-level processing. Nevertheless, across studies, both surface- and deep-level strategies have been found to be associated with single text comprehension (e.g., Dreyer & Nel, 2003; Guthrie, Wigfield, Metsala, & Cox, 1999; McNamara, 2004, 2011; Meyer, Brandt, & Bluth, 1980; Taraban, Rynearson, & Kerr, 2000).

1.2. Strategies for integration

Although strategy use has been well-examined in the literature on single text processing, less is known about students' strategic processing when integrating information across multiple texts. As with single text comprehension, Afflerbach and Cho (2009) introduce a parallel taxonomy of strategies that may be used to support multiple text integration. Again, three types of strategies were identified; those associated with (a) identifying and learning important information, (b) monitoring comprehension, and (c) evaluating text content. An example of identifying important information across multiple texts includes students relating currently read content to information in earlier read texts. Monitoring is reflected in students consulting prior read texts to understand confusing or unfamiliar content in the text before them. Finally, evaluation strategies involve corroboration or the comparing of information in one text to information from previous texts to establish veracity. The categories of strategic processing identified by Afflerbach and Cho (2009) were supported in a think-aloud study by Anmarkrud, Bråten, and Strømsø (2014). Moreover, Anmarkrud et al. (2014) placed particular emphasis on students' use of linking strategies, or strategies involved in the connection of content across texts, be it to identify key constructs (i.e., learn important information), improve comprehension (i.e., monitoring) or to corroborate claims (i.e., evaluation).

Goldman, Braasch, Wiley, Graesser, and Brodowinska (2012) specifically examined the strategy use that differentiated the performance of students learning a lot or a little from a multiple text integration task. The strategies Goldman et al. (2012) identified as supporting integration and differentiating better and poorer learners included engagement in (a) self-explanation (i.e., elaboration or the use of prior knowledge to understand text content), (b) comprehension monitoring, and (c) strategic navigation (i.e., purposeful movement across texts during reading). While Goldman et al. (2012) identified differences in strategic processing based on think-aloud data, Bråten and Strømsø (2011) used factor analysis to classify students' self-reported strategy use during a multiple text task. Two categories of strategies were identified, those reflecting information accumulation and cross-textual elaboration. Information accumulation strategies reflect efforts to gain as much information as possible from available texts, while strategies focused on cross-textual elaboration involve learners' efforts to map relations and to identify similarities and differences across texts. While engagement in cross-textual elaboration was positively associated with multiple text integration, strategies reflecting information accumulation had a negative association with integration. Although more limited than the literature on single text comprehension, a robust research base has emerged associating a variety of strategic approaches (e.g., evaluation, cross-textual elaboration) with multiple text integration (Goldman et al., 2012; Wiley et al., 2009). Collectively, strategies supporting integration may be classified as deep-level, rather than surface-level, in nature (Bråten & Strømsø, 2011; Dinsmore & Alexander, 2012).

1.3. Strategies for video comprehension and integration

While much work has examined students' strategy use when comprehending single texts and, to a more modest extent, when integrating information from across multiple texts, considerably less work has examined the strategies students may use to comprehend and integrate information from video. Indeed, while some studies have examined strategies associated with learning from video, fewer have examined students' strategy use during video viewing, per se. For instance, Endres, Carpenter, Martin, and Renkl (2017) examined the role of free recall prompts versus prompts asking students to recall information and relate it to their own lives on learning from a recorded video lecture, with the later associated with better comprehension performance at a one-week post-test. Yet, less is known about the strategies that students may engage during the course of video viewing.

On a theoretical level, Mayer (2002), in his *Cognitive Theory of Multimedia Learning*, suggests that strategies associated with video and other multimedia comprehension can be thought of as belonging to three broad categories. These are strategies associated with (a) determining relevance (i.e., selecting information), (b) organizing information, and (c) integrating information with prior knowledge. In this way, strategies belonging to the SOI framework (i.e., select-organize-integrate) can be said to parallel strategies associated with expository text comprehension (Mayer, 1996). More recently, Fiorella and Mayer (2013, 2015) have further examined the role of generative strategies (e.g., summarizing, concept mapping, drawing) in supporting learning from text and multimedia, alike.

Empirical studies of video viewing provide an expanded repertoire of strategies that students may use for video comprehension. Caspi, Gorsky, and Privman (2005) identified three categories of strategies used by university students when viewing videos of class lectures. The first was writing or note-taking based on lecture content. The second was pausing and continuing video play-back. The third category reflected the use of strategies associated with navigation or moving backward and forward within video, out of sequence. More generally, Caspi et al. (2005) reported that students felt dissatisfied with their video viewing, potentially as a result of limitations in the transferability of reading comprehension strategies to video comprehension.

At the same time, other studies have found strategy use during video viewing to mirror reading comprehension strategy use. Mu (2010) specifically examined students' note-taking during video viewing and found the characteristics of students' notes, composed during viewing, to be similar to those of notes composed during lecture. In particular, notes during video viewing were factual in nature, reflected content emphasized in video, and decreased in volume during the course of video viewing. Lin (2009, 2011) examined the strategies used by a sample of English Language Learners when watching a language learning video. Lin (2009, 2011) found evidence for cognitive, memory, and compensatory strategy use. Cognitive strategies, like identifying the main idea in video or inferencing, were considered to be strategies directly focused on comprehension. Memory strategies reflected a desire to encode specific content or to retrieve previously stored content. Strategies in this category included organizing new information and drawing on prior knowledge. Compensatory strategies, potentially not generalizable beyond this sample, referred to students' efforts to make up for deficits in linguistic knowledge, for instance by guessing word meanings.

While Mu (2010) and Lin (2009, 2011) identified the strategies used during video viewing as similar to those used when comprehending non-videos (e.g., text, lecture), Caspi et al. (2005) provide evidence for distinct strategy use during video comprehension. Such similarities and differences are encapsulated in Loughlin and Alexander's *Trans-Symbolic Comprehension* (TSC) framework (2012; Loughlin, Grossnickle, Dumas, & Alexander, 2015). Although not specific to video comprehension, the TSC suggests that when processing information of different modalities students apply strategies that are both trans-symbolic (e.g., activating prior knowledge) and symbol-specific (e.g., interpreting symbolic objects) in nature. For instance, Loughlin, Grossnickle, Dinsmore, and Alexander (2015) examined strategy use when students were asked to study paintings. They found strategies reported to include those parallel to strategies used during text comprehension (e.g., activating prior knowledge, elaborating) and those not typically associated with text comprehension (e.g., observing agents/objects/characteristics, interpreting visual elements). In this case, activating prior knowledge may be considered to be a trans-symbolic comprehension strategy, whereas interpreting visual elements may be a symbol-specific strategy for comprehension.

Nevertheless, lingering questions remain regarding which strategies may foster video versus text comprehension. Work by Merkt, Weigand, Heier, and Schwan (2011) provide initial evidence comparing comprehension of information presented vis text versus video. Specifically, Merkt et al. (2011) compared three information presentation formats: a common video, an enhanced video with interactive features, and an illustrated textbook. In the common video condition, participants viewed a history video that they could start, stop, and rewind. Beyond these basic navigation features, offered in the common video condition, the interactive video included a timeline that students could use to navigate to segments of video, a table of contents of video segments, and a list of key terms. The illustrated textbook condition included a literal transcription of the information in video as well as screenshots from the video, a table of contents, and a list of key terms, paralleling features of the interactive video. Comparing these three modes of information presentation, no differences in comprehension performance nor in the number of facts included in participants' written responses were identified. We build on work by Merkt et al. (2011) in a number of ways. First, we more starkly compare text and video conditions, with the text condition in this study only including a transcript of the narration in video, absent images. Second, while Merkt et al. (2011) controlled for reading comprehension strategy use in analyses, we explicitly examine the strategies that students report using when viewing videos versus reading texts. Finally, while Merkt et al. (2011) examined single source comprehension of text versus video, we further investigate students' information integration when multiple sources are presented as texts or videos. To our knowledge, the present study represents the first attempt to compare strategy use during video versus text integration.

1.4. Present study

The goals of this study, then, are to determine which strategies students commonly use when comprehending and integrating information presented via video versus via text and the extent to which the strategies students report using are similar or distinct across mediums. A variety of methods may be used to assess strategy use. These include both online methods, employed during the course of processing (e.g., think-alouds), and self-report methods, gathered retrospectively. In this study, students were asked to report strategy use retrospectively, following task completion, because online measures of strategy use (e.g., think-alouds) were expected to be overly intrusive during the course of video processing. Nevertheless, self-report approaches to strategy assessment carry with them limitations associated with students' under-reporting or over-reporting of strategy use. In particular, we had the following research questions:

1. What strategies do students report using when presented with information via video versus via text?
2. To what extent are there differences in comprehension when students are presented with information via video versus via text? What is the association between modality of information presentation, strategy use, and comprehension?
3. To what extent are there differences in integration when students are presented with information via video versus via text? What is the association between modality of information presentation, strategy use, and integration?

Due to the exploratory nature of this study, specific hypotheses could not be formed. Moreover, investigations comparing text and video comprehension have found mixed results (Yousef, Chatti, & Schroeder, 2014). For instance, while Mayer and Moreno (2002) suggest that, when designed correctly, multimedia information sources can be beneficial for learning, Merkt et al. (2011) found no differences in comprehension performance across video, interactive video, and illustrated text conditions of information presentation. In this study, we expected text to play a facilitative role for comprehension and, especially, for integration, as we expected students to have a greater repertoire of strategies related to processing text-based information available. Nevertheless, specific strategies improving video comprehension and integration could not be fully identified based on prior research.

2. Methods

2.1. Participants

Participants were 78 undergraduate students at a mid-size university in the Mid-Western United States (age: $M = 19.74$, $SD = 1.38$). The sample was 62.82% female (n = 49; male: 33.33%, n = 26). Participants were racially and ethnically diverse: 69.23% White (n = 54), 17.95% African American (n = 14), 6.41% Hispanic/Latino (n = 5) and 2.56% Asian (n = 2). Moreover, 2.56% of participants reported biracial or multiracial status. The sample also represented a variety of class standings. Freshmen constituted 32.05% of the sample (n = 25), 20.51% of the sample were sophomores (n = 16), 25.64% of students were juniors (n = 20), and 20.51% of students were seniors (n = 16). Participants represented a variety of majors and reported an average GPA of 3.22 on a 4-point scale (*SD* = 0.47). One participant declined to provide demographic information.

2.2. Procedure

The study consisted of five parts. First, participants were asked to complete a variety of individual difference measures (e.g., prior knowledge). Second, participants were presented with two information sources: one about penguins and the other about sea turtles. Participants were assigned to one of two experimental conditions, with both information sources presented as either two texts (n = 39) or two videos (n = 39). Third, participants were asked to complete an annotation task. Specifically, after reading or viewing the two information sources, participants were told that the study was being conducted to develop curricular materials for elementary school students; they were then asked to annotate each of the two sources to help younger students better understand them. During the annotation task, participants in the text condition used the track changes feature in Microsoft Word, while participants in the video condition used VideoAnt, a video annotation tool, to identify the questions, comments, and behaviors that they themselves used or would recommend that younger students use to better understand the information provided. However, results from the annotation task are beyond the scope of the present manuscript. Rather, the annotation task can be viewed as a prompt to elicit responses to the fourth part of the study, wherein, participants were asked to report the strategies they used when processing the two information sources. Specifically, the annotation task was expected to elicit reports of strategy use by making students more conscious of the strategies they engaged during processing. Moreover, the annotation task ensured that students viewed or read each information source at least twice (i.e., once during initial processing and a second time for annotation), allowing more strategies to surface, particularly during the second, more deliberate episode of processing. Finally, participants were asked to answer a variety of questions about the two information sources as assessments of comprehension and integration.

2.3. Materials

2.3.1. Prior knowledge

Participants were asked to respond to six, open-ended prior knowledge questions. Three questions were about penguins and three about sea turtles, reflecting the two topics of the task. For instance, participants were asked to *please describe the natural threats that sea turtles face and to explain what is meant by penguins being an indicator species. Correct response to these questions included: Sometimes birds and other animals can eat the baby sea turtles as they are walking to the ocean or The health of penguins can help determine the health of other species living in the same area*, respectively. Each of these open-ended questions were binary scored as correct or incorrect, with scores ranging from zero to six. Two raters scored 17.95% of students' responses (n = 14), with a Cohen's Kappa of 0.76, indicating substantial agreement. Exact agreement was 88.09%, with discrepancies reconciled through discussion.

At pre-test questions were binary scored due to the limited knowledge of our sample, resulting in limited response variability. Moreover, in responding to each of the prior knowledge questions, students were instructed to write *I don't know*, rather than guessing an answer. As such, many prior knowledge responses scoring a 0 were the result of students writing that they did not know the answer to the question. Overall, participants demonstrated only moderate levels of prior knowledge, scoring an average of 2.78 points (*SD* = 1.27), out of a possible six, on the prior knowledge measure. Participants' prior knowledge scores did not differ significantly across conditions ($p = 0.93$).

2.3.2. Information sources

Participants were then presented with two information sources on endangered species, one about penguins and the other about sea turtles. Participants were randomly assigned to process these two information sources either as two texts or two videos, in counterbalanced order. Across conditions, prior to being presented with the two information sources, participants were instructed to: *"Please use these information sources to formulate an argument about species preservation."* Argument tasks have been found to foster integration in prior research (e.g., Wiley & Voss, 1999).

Sources were developed by first identifying two videos of similar structure and format. Videos were selected based on content (i.e., focusing on endangered species), as well as to be similar in length and style. Both videos were expository in nature and showed animations, accompanied by narration, but with no human speaker visible. The animation in both videos illustrated information presented via the accompanying narration, but did not provide any unique information. For instance, in the sea turtle video, as each threat faced by sea turtles was explained in the narration, these were also depicted through accompanying animations. Both videos were created by TEDEd, a video production platform that creates animated videos of academic content for teachers. Selecting TEDEd videos allowed us to present participants with naturalistic materials, while at the same time ensuring uniformity of format. Although both information sources were thematically related in their discussion of endanger species, the two sources did not explicitly reference one another.

After videos were selected, they were transcribed to create textual versions of each source. Texts were exact transcriptions of video narrations. Texts were presented digitally to participants as Microsoft Word documents and included a title, author, and attribution listed at the top of the page. Text titles were identical to the titles of each video. An author was added to each text, reflecting the name of the TEDEd video creator. Production company was listed as the attribution below the author's name (i.e., TEDEd: Lessons worth sharing).

2.3.2.1. Penguins. The penguin information source was titled, *The popularity, plight, and poop of penguins.* The text was 767 words in length, corresponding to a video that was 5 min and 23 s in length. A transcript of the narration in the penguin video, used in the text condition, had a Flesch-Kincaid Grade Level of 12.2 and a Flesch-Kincaid Reading Ease of 48.9, indicating its suitability for use with an undergraduate audience.

2.3.2.2. Sea turtles. The sea turtle information source was titled, *The survival of the sea turtle*. The text was 655 words in length, corresponding to a video that was 4 min and 25 s in length. The transcript of the turtle video had a Flesch-Kincaid Grade Level of 9.7 and a Flesch-Kincaid Reading Ease of 62.1.

2.3.3. Strategy reporting

An open-ended self-report question was used to assess participants' strategy use. After viewing the two videos or reading the two texts and completing an annotation task, participants were asked to list the strategies they used while processing the two information sources. Specifically, participants were asked: *"What strategies did you use in comprehending the two information source? What strategies would you recommend that others use in comprehending the information?"* Prior work has similarly used open-ended queries to assess students' strategic processing (Chang, 2005; Karpicke, Butler, & Roediger, 2009). Retrospective report was adopted as a method for strategy assessment because online strategy measures (e.g., think-aloud) were considered to be too demanding to use during the course of video processing. Nevertheless, such a method carried limitations typically associated with self-report.

The strategies students cited were categorized and participants received a binary score for each strategy category reflecting whether or not they had employed strategies within that category. Participants received only one point per strategy category, even if they discussed using the same strategy multiple times. A binary scoring was adopted due to the restricted range of strategies reported. For the vast majority of students, only one strategy per category was reported. In fact, only a maximum of two strategies were reported in accordance with any one strategy category. As such, making all strategy categories binary scored allowed for a variety of non-parametric analyses to be conducted and aided interpretation.

Based on prior research, we expected participants to report both surface-level (e.g., highlighting) and deep-level strategy use (e.g., elaboration or connecting to prior knowledge) for text and video comprehension (Dinsmore & Alexander, 2012; Loughlin et al., 2015). Initially, we were specifically looking for strategies consistent with the SOI framework (Mayer, 1996) and aligned with students' attempts to determine relevance, organize information, and integrate information within sources, across sources, and with prior knowledge. However, students in our sample reported many more strategies than those captured by the SOI framework, while, at the same time, reporting a limited degree of integrative strategy use. As such, a bottom-up coding approach was adopted.

Students' reported strategies were first placed into fine-grained categories, reflecting the particular terms participants used in describing strategy use. These were then collapsed into larger strategy categories. While some strategies (e.g., self-explanation, perspective taking) were collapsed into a more general category of deep-level strategy use, other strategies could not be definitively classified as surface-level or deep-level in nature. For instance, the annotation strategy category included both students' reports of highlighting, corresponding to more surface-level strategy use, and note-taking, potentially to support organization, a deeper-level process. Likewise, students' monitoring of comprehension may have been indicative of metacognitive, rather than cognitive strategy use. And, certain strategies cited, like identifying important information or directing attention, could not be definitively classified as surface-level or deep-level in nature. As such, strategies were not collapsed into surface-level and deep-level categories, allowing a comprehensive variety of strategies to be associated with comprehension and integration. Two raters coded 21 student responses (26.92% of the sample) to the open-ended strategy question. Cohen's kappa inter-rater agreement for categorizing students' strategy use was 0.84, indicating almost perfect agreement. Disagreements were resolved through discussion. Strategies categories are summarized in Table 1.

2.3.4. Performance

Participants were then asked to complete measures of comprehension and integration. While comprehension questions addressed information reflected in each source separately, the integration prompts required students to draw on information presented across the two sources to formulate a response.

2.3.4.1. Comprehension

2.3.4.1. Comprehension. Comprehension was assessed using multiple choice and open-ended response questions. All comprehension items tapped information coming from a single source rather than across sources.

First, participants were asked 10 factual multiple-choice questions. An example question was: *At what age do adult, female turtles start to reproduce*, with participants able to choose from the following options: *two years, ten years, twenty years, fifty years,* or *I don't know*. Responses to multiple-choice questions were scored as correct or incorrect, with a maximum score of 10 points possible. Kuder-Richardson's 20 for the 10-item scale was $\alpha = 0.33$, indicating poor internal consistency. This is attributable to comprehension items corresponding to the sea turtle and penguin sources independently and to the relatively limited number of items included. Nevertheless, analysis of performance on the multiple-choice comprehension assessment should be interpreted with caution due to the low reliability of this measure.

Second, comprehension was also assessed by asking students to respond to six open-ended questions. Three questions address content in the penguin source and three questions addressed sea turtle content (e.g., *Based on the information presented, describe sea turtle reproduction*). Open-ended responses were scored on a three-point scale, according to whether they were inaccurate (0), limited (1), or fully elaborated (2) answers. For instance, a student responding "*they lay eggs on the beach*" to the above question, received a score of one for their answer, while students responding that: "*When a sea turtle is about 2 decades old, she climbs onto the beach and digs a hole. She then lays leathery ping pong sized eggs and covers them with sand. 80% of these eggs hatch and then half of those that do hatch make it to the ocean,*" received a score of two for a fully elaborated answer. Students could receive a maximum score of 12 points on this open-ended comprehension assessment. Two raters coded 21 student responses (26.92%), with Cohen's kappa inter-rater reliability equal to 0.81, indicating almost perfect agreement. Comprehension items duplicated those presented to students as part of the prior knowledge measure but were scored using an expanded three-point, rather than binary, scale.

2.3.4.2. Integration. Integration was assessed by asking participants to respond to two different kinds of prompts. The first integration prompt closely mirrored the task participants were assigned prior to being presented with the two information sources. Specifically, students were told: *You are writing an argument about species preservation. What information, from the two sources about sea turtles and penguins, would you be sure to include? Please include all information necessary to support your argument about species preservation.* The coding scheme for

Table 1
Strategies reported.

Strategy	Explanation
Note-taking	Annotating the information source itself (e.g., highlighting) or taking notes based on information in the source
Id-ing Main Ideas/Important Info.	Identifying the main idea or most important information in a source
Monitoring Comprehension	Attending to or reflecting on comprehension quality
Directing Attention	Consciously focusing or directing attentional and cognitive resources to information sources
Deep-Level Strategy Use	Strategy use associated with information transformation or critically analytically processing information (e.g., self-explanation, evaluation, perspective taking)
Vocabulary	Strategies for learning or identifying the meaning of vocabulary
Connecting to Visuals	Attending to, comprehending, or evaluating visual information in video
Connecting to Prior Know.	Applying prior knowledge to understanding source content
Re-Reading	Reviewing textual material
Re-Viewing and Navigation	Re-viewing or navigating (e.g., pausing, rewinding) videos
Interest/Affective Response	Affective responses to content (e.g., interest, surprise)
Memory Focused	Strategies focused on directly memorizing information, without further processing or transformation
Summarizing	Summarizing or reducing information volume
Task-Focused	Explicitly reflecting on task demands or connecting source-based information to task demands
Other	

Table 2
Response integration coding scheme and sample responses.

	Response Level	Example
0	**Non-Responsive**	No relevant information provided
1	**Singular Information**: Refers to only one source	"Sea turtles only have a 10% chance of survival and humans are making it more difficult with our pollution"
2	**Linear Presentation**: Discuss two information sources independently with no integration.	"Sea turtles - Previously, out of the about 1000 eggs laid only 10 of them made it to adulthood. Now, with human contributions, only about 2 eggs make it to adulthood. Penguins - Even though we are the greatest threat to the penguin population, we are their greatest chance of survival as well."
3	**Generic Integration:** Only integration; sources not explicitly identified and no specific content provided.	"**Species located in the ocean or by the ocean have a large risk of going extinct**." "**I would just try to enforce how much of an impact we have as humans** to change their lives for better or worse."
4	**Partial Integration:** Evidence for integration but either no explicit reference to separate sources *or* no specific source-based information provided.	*Integration, explicit reference, no specifics:* "As humans, we have a responsibility to protect species such as <u>penguins and sea turtles</u>. We need to change our ways and **eliminate pollution and all of our negative influences in order to ensure the survival of these two species.**" *Integration, specifics, but not explicit reference:* "*Overfishing and pollution*, **talking about how both those kill the animals' food supply which can cause them to die**."
5	**Complete Integration:** Evidence of integration, with explicit reference made to separate sources, and specific source content provided.	"I would include the **rarity of each species.** <u>Turtles</u> especially face great odds, *with 20/1000 surviving to breeding age without human intervention and 2/1000 with human intervention*. By focusing on the miraculousness of a single sea turtle, arguments about *oil spills and pollution* would be more powerful because it would be harder to think "there are plenty more out there." **The same would apply to penguin species that are becoming endangered.** <u>Penguins</u> fill an especially important *ecological niche. Without them, the ecology of their environments, including the food chain would be disrupted*. Their food chain is disrupted by *global warming and overfishing*, two of the main problems they face. They like to *eat krill, and global warming is heavily affecting those populations*. Things that may seem insignificant or unrelated are probably contributing to the large-scale problems in species decline, so it is important to consider the impact of every small action, such as pollution.

Note: **Integrative statements are bolded;** <u>explicit references underlined</u>; *specifics are italicized.*

participants' responses was based on the Documents Model (Britt et al., 1999, pp. 209–233; Perfetti et al., 1999), which emphasizes the importance of students both integrating information across sources and accurately associating particular pieces of information with their sources of origin. Participants' responses were coded for their degree of (a) integration, (b) explicitness in mapping information as coming from either the sea turtle or the penguin source, and (c) specificity in providing evidence from the two sources. Two raters scored 21 participant responses (26.92%) and achieved a degree of inter-rater reliability of Cohen's $\kappa = 0.64$, indicating substantial agreement. Disagreements in coding were reconciled through discussion. The coding scheme and sample responses are presented in Table 2.

Second, participants were asked to compare and contrast the two information sources. In particular, students were asked: *Based on the two information sources, identify the similarities and differences between sea turtles and penguins. What do these two species have in common? What is distinct about them? What did the two information sources have in common? What made them distinct?* Participants received one point for each unique similarity or differences correctly identified. Two raters scored all participant responses for the number of similarities and differences identified, with Cronbach's alpha reliability equal to 0.76, indicating an acceptable degree of consistency. Discrepancies in scoring were reconciled through discussion. Descriptive statistics for all target variables are included in Table 3.

Table 3
Descriptive statistics for outcome variables.

Variable	Text M(SD)	Video M(SD)	Text Min/Max	Video Min/Max	Text Skewness/Kurtosis	Video Skewness/Kurtosis
MC Comprehension	7.36 (1.48)	7.56 (1.59)	4.00/10.00	3.00/10.00	−0.15/-0.46	−0.73/0.85
Open-Ended Comprehension	7.67 (1.83)	8.33 (1.74)	5.00/12.00	5.00/12.00	0.50/-0.16	−0.01/-0.30
Response Integration	3.49 (1.17)	3.69 (0.98)	1.00/5.00	1.00/5.00	−0.44/-0.69	−1.29/1.67
Comparative Integration	5.10 (2.88)	4.49 (1.97)	1.00/18.00	2.00/9.00	2.63/10.01	0.49/-0.72

Note: Cut-off values was ± 1 for Kurtosis and ± 2 for Skewness. Due to concerns with non-normality, a histogram of comparative integration scores, for the text condition, was visually inspected and one outlier, reporting 18 similarities and differences, was removed.

3. Results

3.1. Research question 1. strategy use across modality conditions

The first research question examined the prevalence of various strategy categories cited across modalities of information presentation (i.e., video versus text). Across conditions, the most common strategies reported involved note-taking (32.05%, n = 25) and identifying the main idea or otherwise judging information as important (32.05%, n = 25).

A series of chi-squared tests of association were used to examine whether there were differences in the prevalence of strategies reported across modality conditions. Differences in strategy use across conditions are summarized in Table 4. First, directing attention or maintaining focus was a strategy more commonly cited in the video versus the text condition [text: 7.69%, n = 3; video: 38.46%, n = 15; $X^2(1) = 10.40$, $p < 0.001$, Cramer's $V = 0.37$]. Likewise, differences were reported in the prevalence of re-reading (text: 25.64%, n = 10; video 0%, n = 0) versus re-watching (video: 15.38%, n = 6; text = 0%, n = 0) strategies reported [rereading: $X^2(1) = 11.47$, $p = 0.001$, Cramer's $V = 0.38$; re-watching: $X^2(1) = 6.50, p < 0.01$, Cramer's $V = 0.29$]. However, when re-reading and re-watching strategy use, including navigation, were collapsed into a single reviewing strategy use category, no significant differences were found ($p = 0.26$). Finally, students in the text condition more frequently reported strategy use related to understanding difficult vocabulary (25.6%, n = 10), than did students in the video condition (5.1%, n = 2), $X^2(1) = 6.30$, $p < 0.05$, Cramer's $V = 0.28$. As may be expected, significant differences were found in the prevalence of students reporting using visuals across conditions,

Table 4
Strategies reported across modality conditions.

Strategy	Example	Text	Video	Total
Note-taking	"… circle, highlight or underline what they think is important information."	30.77% (n = 12)	33.33% (n = 13)	32.05% (n = 25)
Id-ing Main Ideas/Important Info.	"I would recommend finding the important key points in the articles" "I looked for the big idea of each video and paid less attention to minor details."	38.46% (n = 15)	25.64% (n = 10)	32.05% (n = 25)
Monitoring Comprehension	"… tried to understand what it was trying to say. While I was reading I would stop after the end of each paragraph to comprehend what I read."	30.77% (n = 12)	20.51% (n = 8)	25.64% (n = 20)
Directing Attention***	"The strategies I used was to listen closely to the information that was given."	7.69% (n = 3)	38.46% (n = 15)	23.08% (n = 18)
Deep-Level Strategy Use	"visualization of the animals in their natural habitats, the threats they face, their struggles, their actions as described in the article" "I also thought about questions I had myself"	25.64% (n = 10)	17.95% (n = 7)	21.79% (n = 17)
Vocabulary*	"I read the words and if I didn't know one, I would look at context clues to determine the meaning of that word."	25.64% (n = 10)	5.13% (n = 2)	15.38% (n = 12)
Connecting to Visuals***	"Study the diagrams when presented. Seeing the statistics as well as hearing them really helped me."	0% (n = 0)	28.21% (n = 11)	14.10% (n = 11)
Connecting to Prior Know.	"I connected what I was reading to images that I have previously seen or information that I previous read."	12.82% (n = 5)	12.82% (n = 5)	12.82% (n = 10)
Re-Reading***	"I reread the material and I read slower than I did the first time on the second read."	25.64% (n = 10)	0% (n = 0)	12.82% (n = 10)
Re-Viewing and Navigation**	"While analyzing the two sources, I made sure to pause."	0% (n = 0)	15.39% (n = 6)	7.69% (n = 6)
Interest/Affective Response	"I found the topics interesting so it wasn't hard to pay attention."	12.82% (n = 5)	10.26% (n = 4)	11.54% (n = 9)
Memory Focused	"I committed the information to memory because the videos were short enough to remember the major points."	7.69% (n = 3)	15.38% (n = 6)	11.54% (n = 9)
Summarizing	"I summarized the paragraphs to still hold the same information, but simplify it so it was easy to understand."	10.26% (n = 4)	2.56% (n = 1)	6.41% (n = 5)
Task-Focused	"I also looked for any facts that would be beneficial to know to help support an argument for this topic."	10.26% (n = 4)	0% (n = 0)	5.13% (n = 4)
Other		15.38% (n = 6)	28.21% (n = 11)	21.79% (n = 17)

Note: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

$X^2(1) = 12.81$, $p < 0.001$, Cramer's $V = 0.41$. Specifically, while 28.21% of participants in the video condition (n = 11) reported using this strategy, with no students in the text condition reported doing so, as the lack of visuals was a limitation of the text-based information presentation condition.

No significant differences were found in the prevalence of participants reporting note-taking ($p = 0.81$), connecting new information with prior knowledge ($p = 1.00$), identifying important information ($p = 0.23$), monitoring comprehension ($p = 0.30$), or engaging deep-level comprehension strategies ($p = 0.41$) across conditions. Strategies where the expected count per cell was less than five were excluded from analysis due to assumption violations.

Participants in the video condition did devote significantly more time to processing the two information sources than did participants in the text condition. This was true for both the turtle, $F(1, 76) = 18.01$, $p < 0.001$, $\eta^2 = 0.19$, and the penguin source, $F(1, 76) = 14.36$, $p < 0.001$, $\eta^2 = 0.16$. Specifically, participants devoted an average of 4.43 min ($SD = 0.78$) to viewing the turtle information source, as compared to 3.40 min ($SD = 1.29$) spent reading. In the case of the penguin source, participants in the video condition devoted 5.27 min ($SD = 1.64$) to viewing, as compared to an average of 3.97 min spent reading ($SD = 1.95$). For the sake of comparison, it is important to note that the turtle video was 4.42 min in length, while the penguin video was 5.38 min in length. Nevertheless, time devoted to reading texts or viewing vides cannot be associated with depth of processing. Time data have been variability interpreted as reflecting engagement, challenges in comprehension, effort expended, and strategy use, be it surface- or deep-level, at least within the context of text processing (Ainley, Hidi, & Bernforff, 2002; Bråten, Anmarkrud, Brandmo, & Strømsø, 2014; List & Alexander, 2017). Indeed, in this study, time devoted to source use was not associated with the total number of strategy categories students reported engaging ($p = 0.38$).

3.2. Research question 2. comprehension

On average, students did well on the two comprehension measures. Average scores on the multiple-choice items were 7.46 ($SD = 1.53$), out of a possible 10 points. On the open-ended comprehension questions, participants' average scores were 8.00 ($SD = 1.80$) out of a possible 12 points. Participants' comprehension scores did not differ according to modality of information presentation. This was true for both the multiple choice ($p = 0.56$) and the open-ended comprehension ($p = 0.10$) questions. Point-biserial correlations between each strategy category and each of the four response metrics is included in Table 5.

We then examined strategy use in association with comprehension performance. Specifically, backwards elimination regressions were run with prior knowledge, information presentation condition (i.e., text or video), an interaction term between condition of information presentation and time, and binary variables for students' use of each strategy category entered at Step 1, and non-significant predictors iteratively removed from the model. A binary coding was used to enter condition of information presentation into the model (i.e., text = 0, video = 1). Backwards elimination was adopted as an analysis approach due to the large number of strategy categories emerging from this study; backwards elimination was used as a somewhat exploratory technique to identify those strategy categories most associated with comprehension and integration performance. Separate regression models were run for each comprehension outcome measure due to the variable format of these indicators (i.e., multiple choice versus open-ended constructed response). As a note, only the eleven most commonly cited strategy categories, reported by at least 10% of respondents, were entered as predictors. Rereading and re-watching strategies were collapsed into a single "reviewing" category for the regression.

Separate regressions were run for multiple choice and open-ended comprehension scores. The final model for multiple-choice scores was not significant ($p = 0.21$). However, the final model for open-ended

Table 5
Point-biserial correlation between each strategy category and performance outcomes.

Strategy Category	MC Comprehension	Open-Ended Comprehension	Overall Integration	Relational Integration
Note-taking	0.05	0.06	0.01	−0.20
Identifying the Main Idea	0.05	0.22	0.06	0.16
Monitoring Comprehension	0.09	−0.05	−0.05	−0.07
Directing Attention	0.05	−0.02	0.24*	0.11
Deep-Level Strategy Use	−0.06	−0.10	−0.20	0.22
Vocabulary	0.08	−0.06	0.06	−0.05
Connecting to Visuals	0.14	0.12	0.09	−0.01
Connecting to Prior Knowledge	−0.02	0.13	0.08	0.24*
Reviewing	−0.01	−0.09	−0.07	−0.05
Interest/Affective Response	0.08	0.13	−0.12	−0.04
Memory Focused	−0.03	0.11	−0.20	−0.00

Table 6
Open-item comprehension model summary.

	B	SE(*B*)	*β*	*p*	Correlations		
					Zero	Partial	Semi-Partial
Mode of info. presentation	0.79	0.40	0.22	0.05	0.19	0.22	0.22
Identify important info	0.94	0.43	0.25	0.03	0.22	0.25	0.24

$F(2, 75) = 3.87$, $p < 0.05$, $R^2_{adj} = 0.07$.

comprehension performance was significant [$F(2, 75) = 3.87$, $p < 0.05$, $R^2_{adj} = 0.07$], indicating a small-medium effect. The two predictors retained in the final model predicting open-ended comprehension were condition of information presentation ($\beta = 0.22$, $p = 0.05$) and students' use of strategies associated with identifying important information or main ideas ($\beta = 0.25$, $p < 0.05$). A summary of the final model is included in Table 6.

Once a final model was developed through backwards elimination, an updated regression model was run examining the interaction between condition and use of strategies associated with comprehension performance (i.e., identifying important information) and controlling for prior knowledge. However, while condition of information presentation [Wald $X^2(1) = 3.89$, $p < 0.05$] and using strategies associated with identifying important information [Wald $X^2(1) = 4.69$, $p < 0.05$] were significant effects in the model, their interaction was not significant ($p = 0.82$).

3.3. Research question 3. integration

Participants' average integration response scores were 3.59 ($SD = 1.07$), on a 5-point scale, indicating attempts at integration but limitations either in accurately mapping content to sources of origin or in providing specific information from sources. Participants' average scores on the comparative integration measure were 4.79 ($SD = 2.47$), reflecting an average of 3.53 ($SD = 1.93$) similarities and 1.27 ($SD = 1.05$) differences identified. Across responses, students identified a maximum of 13 similarities and 5 differences across sources. Neither response integration scores ($p = 0.40$) nor comparative integration scores ($p = 0.28$) differed across conditions of information presentation.

Two backwards elimination regression models were run, with students' integration and comparison scores as dependent variables. Again, prior knowledge, condition of information presentation, an interaction term between condition and time on source use, and binary variables for strategies used were entered as predictors into the model at Step 1. Condition of information presentation was again binary scored (text = 0; video = 1). The final model predicting response integration scores was significant [$F(3, 74) = 3.56$, $p < 0.05$, $R^2_{adj} = 0.09$], reflecting a medium sized effect. Predictors retained in the final model

Table 7
Response integration scores model summary.

	B	SE(*B*)	*β*	*p*	Correlations		
					Zero	Partial	Semi-Partial
Directing attention	0.63	0.28	0.25	0.03	0.24	0.25	0.24
Deep-level comprehension	−0.63	0.30	−0.25	0.04	−0.20	−0.24	−0.23
Connecting to Prior Knowledge	0.69	0.38	0.22	0.07	0.08	0.21	0.20

$F(3, 74) = 3.56$, $p < 0.05$, $R^2_{adj} = 0.09$.

included strategy use associated with directing attention ($\beta = 0.25$, $p < 0.05$), engaging in deep-level strategy use ($\beta = -0.25$, $p < 0.05$), and connecting new information with prior knowledge ($\beta = 0.22$, $p = 0.07$). Please note that deep-level strategy use was a significant, negative predictor in the model. However, there was no significant effect for condition of information presentation. A model summary is included in Table 7.

A model was run examining the possible interactions between condition of information presentation and strategies associated with integration performance (i.e., directing attention, deep-level strategy use, and connecting information with prior knowledge); prior knowledge was controlled for. A main effect for deep level strategy use was identified [Wald's $X^2(1) = 4.12$, $p < 0.05$]; however main effects for condition of information presentation ($p = 0.86$), directing attention ($p = 0.06$), and connecting to prior knowledge ($p = 0.19$) were not significant, nor were interactions between condition of information presentation and strategy use ($ps > 0.55$).

The model predicting comparative integration scores was also significant, $F(2, 74) = 3.76$, $p < 0.05$, $R^2_{adj} = 0.07$, indicating a medium effect. Predictors retained in the final model were strategies associated with directing attention ($\beta = 0.22$, $p = 0.05$) and connecting content with prior knowledge ($\beta = 0.24$, $p < 0.05$). However, there was no significant effect for condition of information presentation. See Table 8 for a model summary.

A model with interaction effects between condition of information presentation and strategies associated with comparative integration

Table 8
Comparative Integration Scores Model Summary.

	B	SE(*B*)	*β*	*p*	Correlations		
					Zero	Partial	Semi-Partial
Connecting to Prior Know.	0.38	0.17	0.24	0.03	0.21	0.25	0.24
Directing Attention	1.01	0.52	0.22	0.05	0.19	0.22	0.22

$F(2, 74) = 3.76$, $p < 0.05$, $R^2_{adj} = 0.07$.

(i.e., directing information, connecting with prior knowledge) was run, with prior knowledge controlled for. However, only main effects for prior knowledge [Wald's $X^2(1) = 4.16, p < 0.05$] and strategy use associated with directing attention [Wald's $X^2(1) = 4.13, p < 0.05$] were identified. Neither of the interactions between condition of information presentation and strategy use categories were significant ($ps > 0.24$).

4. Discussion and implications

This study examined differences in strategy use when students were presented with information either through videos or through text. Moreover, strategy use was examined in association with students' comprehension and integration of information presented across modalities. This study was informed both by models of text comprehension and integration and by strategic processing frameworks of textual and non-textual materials.

4.1. Research question 1. strategy use across modalities

The first research question examined students' strategy use across modalities of information presentation (i.e., text or video). Across conditions, students reported using, on average, 2.54 strategies (*SD* = 1.22) during information processing, indicating somewhat limited strategy use. The number of strategy categories reported across information presentation conditions did not significantly differ when students were presented with content via two videos versus via two texts. Nevertheless, while the volume of strategy use, overall, may not have differed across conditions, there was evidence that the nature of the strategies employed was indeed distinct.

The strategies students reported using for text and video processing provide empirical support for Loughlin et al.'s (2015) Trans-Symbolic Comprehension framework. Strategies reported were both trans-symbolic and symbol-specific in nature. For instance, while connecting information to visuals was a symbol-specific strategy that was only cited in the video condition, other strategies (e.g., connecting information to prior knowledge) were trans-symbolic, commonly cited across both conditions. Moreover, an additional category of strategies to emerge from this study were strategies that were highly prevalent within one, but not exclusive to, modality condition. For instance, presenting information via text seemed to cue students' adopting of vocabulary-related strategies (e.g., using context clues to learn word meanings) to a greater extent than did presenting information via video. These findings suggest that particular modalities of information presentation not only demand unique, symbol-specific processing but also cue the use of certain trans-symbolic strategies over others. At the same time, certain strategies may only manifest within particular mediums. For instance, connecting to visuals was a strategy that was cited exclusively within the video condition, because the texts introduced to students in our study did not include graphic information. Likewise, strategies associated with highlight text, although not with note-taking more broadly, may be considered to be only possible within the text processing condition. More work is needed to disentangle those strategies that are exclusively supported within particular mediums from those that are just more commonly engaged by learners. The difficulty of disentangling such strategies may be exacerbated by our use of self-report to assess strategy use.

When processing both texts and videos, students reported using strategies (e.g., re-reading, summarizing, elaboration/connecting information to prior knowledge) previously well-established in the text comprehension literature. Mayer's SOI framework (1996) can be used as a taxonomy to determine patterns in students' strategy use. In particular, students most commonly reported using strategies associated with selecting important information, including directing attention and identifying important information or main ideas in sources. The use of integration strategies, like connecting information with prior knowledge and deep level strategy use, was also evidenced. However, students seemed to be limited in reporting strategies associated with organization or the connecting and systematizing of information within sources.

There was also a distinct dearth of cross-source integrative strategy use. Limitations in cross-source integration have previously been identified in studies of multiple text processing (e.g., Britt & Aglinskas, 2002; Bråten & Strømsø, 2011). At the same time, students obviously evidenced some degree of integration in composing arguments about species preservation and comparing the two information sources. Limitations in reported cross-source integrative strategy use may therefore arise from students' insufficient meta-cognitive awareness of processing during reading or viewing. Alternately, students may have integrated content only retrospectively, when promoted to do so, rather than during initial processing.

More research is needed to understand the manifestation of particular strategies within the context of information being presented through a variety of modalities. For instance, both rereading, cited in the text condition, and re-viewing, reported in the video condition, were strategies associated with revisiting previously processed content. Nevertheless, the presentation of these strategies across conditions was quite distinct. While re-reading was described as revisiting previously read segments of text, out of sequence, reviewing was associated with a wider variety of navigation strategies aimed at regulating both the sequence and speed of information flow. Specifically, the re-viewing category also included behaviors like pausing and restarting the video and navigating to earlier video segments in playback, behaviors that did not seem to have an analog during reading. At the same time, examining the length of time students devoted to video viewing, relative to video length, suggests that students did not engage in an extensive amount of navigation-based strategy use.

4.2. Research question 2: comprehension

When only condition of information presentation was examined, participants' comprehension performance did not differ significant between text and video, neither when comprehension was assessed via multiple choice items nor via open-ended questions. These findings are difficult to compare to earlier work as limited prior work has examined students' comprehension across text and video. At the same, a generally facilitative effect has been found for the inclusion of images alongside linguistic content, provided images are germane, rather than superfluous, to comprehension, and are attended to by students (Ametller & Pintó, 2002; Chun & Plass, 1996; Mayer & Anderson, 1991; Mayer & Gallini, 1990). Nevertheless, there are a variety of reasons why differences in comprehension may not have emerged. First, there may have been a ceiling effect in students' performance, particularly on the multiple-choice items, decreasing variability in comprehension scores. This may have emerged either due to the low comprehension demands of the study materials, created as videos for classroom use, or because of an over-exposure effect. Participants were asked to read or view and then to annotate the texts and videos, resulting in prolonged exposure to source content. More stark differences in comprehension performance may emerge across modalities when participants are confronted with more challenging academic material. Second, the degree of uniformity in students' strategic processing across modality conditions may have resulted in their processing sources in the same manner or to the same extent, depressing differences in comprehension across modalities. As a final point, the multiple-choice based comprehension measure in this study had a poor degree of internal consistency, reducing our ability to identify differences in comprehension across conditions.

Comprehension performance was jointly predicted by condition of information presentation and strategy use. Modality of information presentation and the strategy categories students reported using were not associated with performance on multiple choice questions. However, task condition and using strategies associated with identifying important information were predictive of performance on open-ended comprehension questions. In particular, viewing, rather than reading, the information sources and identifying important information both facilitated comprehension. Video viewing may have aided comprehension, albeit to a somewhat limited extent, for a number of reasons. First, video may have been a more engaging medium for students, potentially better motivating comprehension (Guo, Kim, & Rubin, 2014). Moreover, students may have had an easier time comprehending spoken rather than written discourse (Mayer, 2002). Finally, videos may have supported comprehension through the provision of visual and cognitive aids (Mayer, 2002; Scheiter, Schüler, & Eitel, 2017). In particular, some statistical information regarding the percentage of sea turtles and penguins surviving under different conditions was especially well-illustrated by the videos and later tapped in comprehension questions. Of course, identifying important information in sources is a strategy commonly associated with improved comprehension through its directing of cognitive resources to processing key content (Afflerbach, 1990; Mayer, 1996; McCrudden & Schraw, 2007). Nevertheless, it is important to note that these findings are the result of an exploratory regression technique (i.e., backwards elimination) and more work is needed to determine the specific strategies, beyond those reported, that may support comprehension.

4.3. Research question 3: integration

Integration did not differ across conditions of information presentation. In part, this may have been due to the overall limited degree of integration and integrative strategy use exhibited across the two conditions. Participants in this study were not explicitly cued to integrate content across sources prior to viewing or reading, rather they were asked to process the sources to form an argument. While argument tasks have been found to foster integration during multiple text tasks (e.g., Wiley & Voss, 1999), the extent to which this task formulation also served to foster video integration has yet to be determined.

A variety of strategy categories were associated with both measures of integration, as determined by backwards elimination regressions. Strategies associated with directing attention and connecting content with prior knowledge were found to predict response integration scores. Interestingly, deep-level strategy use was found to have a negative relationship with students' response integration. This may have been the case for a variety of reasons. In part, it may have been that the componential nature of the deep-level strategies factor meant that some deep-level strategies in this category facilitated integration, while others did not. It is important to note that strategies reflecting deep-level strategy use, but constituting a stand-along category (i.e., connecting information with prior knowledge), were positive predictors of integration. Finally, the deep-level strategies that students did employ (e.g., questioning) may have focused their attention on single text comprehension, absorbing cognitive resources that could otherwise have been devoted to integration.

Strategies reflecting directing attention and connecting content with prior knowledge were retained in the final model predicting comparative integration scores, or the number of similarities and differences that students identified across texts. Importantly, these strategies corresponded to Mayer's (1996) SOI framework, reflecting the deliberate focusing on information and the integration of information with prior knowledge.

Due to the exploratory nature of backwards elimination as a regression technique, a variety of strategies were able to be associated with integration performance. The variability of strategies associated with the two different measures of integration (e.g., directing attention) suggest that there may be a number of paths to supporting students' connecting of information across sources. Nevertheless, it seems that the use of elaborative strategies, or those associated with connecting new content to prior knowledge, may be particularly important; indeed, the use of these strategies was found to be associated with both measures of integration. The importance of elaborative strategy use has been well-established in studies of single text comprehension (Coté, Goldman, & Saul, 1998; Magliano, Trabasso, & Graesser, 1999; McNamara, 2004), and may need to be further emphasized within the context of multiple text and video integration.

This study contributes to the literature on multiple source integration in at least three ways. First, it is among the first to compare comprehension and integration when learners are presented with information via video versus via text. Second, in examining strategy use in association with comprehension and integration, this study provides empirical support for the Trans-Symbolic Comprehension Framework, validating students' use of both trans-symbolic and symbol-specific strategies when processing information presented via different modalities. Third, this study robustly assesses both single text comprehension and multiple text integration through multiple measures of each and identifies strategies that may be used to enhance these outcomes. Moreover, the coding scheme used to score students' integrative responses as well as the source comparison task offer promising avenues for assessing integration in novel and more explicit ways.

4.4. Limitations

Despite these strengths, a number of limitations must be acknowledged. For one, strategy use in this study was assessed via self-report. Although self-report, open-ended strategy questions have been used in prior research, these present at least three limitations. First, students may have under-reported the strategies they actually used during reading or viewing, particularly if they had limited metacognitive awareness of processing. Conversely, students may have over-reported strategies used. We were, admittedly, less concerned with this later point, since we were interested in the repertoire of strategies students had access to when processing videos versus texts. Nevertheless, the intervening annotation task, in particular, may have resulted in students reporting the use of strategies not actually engaged during processing. As an additional point, students who were more elaborative in their writing may have reported more strategies and performed better on measures of integration, only as a result of fluency related factors. Future work should control for writing ability, as well as comprehension skills, in examining strategy use during reading and video viewing. The strategies students reported had to be coded, and therefore interpreted, by study authors. Other self-report measures, such as asking learners to check-off strategies on an inventory, may have resulted in students reporting a more comprehensive set of strategies; however, the limitation of such approaches is a possibility of over-reporting. Adding further indicators of strategic processing, such as process data from think-alouds or eye-tracking, would greatly enrich the strategy data reported here, although these are difficult to collect during video viewing.

This study sought to examine strategy use in a comprehensive fashion and used backwards elimination, an exploratory technique, to identify those strategies that were associated with comprehension and integration. To be maximally inclusive of strategies reported, all strategies reported by 10% or more of the sample were considered. However, this means that some of the strategies reported were potentially used fairly infrequently within any particular condition. This leads to challenges in the interpretation of results as well as in their generalizability. Follow up analyses should more robustly examine, and potentially elicit, students' strategy use during processing.

For another, the materials selected for this study were only moderate in difficulty. This may have resulted in limited strategic processing during reading or video viewing or in ceiling effects on measures of comprehension. School-level materials were selected because they were professionally and uniformly made through the TedED production company and mirrored the types of materials that typical elementary and secondary students may encounter when using instructional videos. Further, video selection allowed strategy use to be captured by instructing participants to report the strategies they would recommend to help elementary school students' comprehension. At the same time, selecting more difficult videos, and corresponding texts, may result in greater strategy use during processing or greater variance in comprehension and integration scores. As a further note, the texts in this study included only transcripts of the narration included in videos. Following methodologies developed by Merkt et al. (2011) further studies should compare students' strategic processing when comprehending videos, texts, and illustrated texts, including screenshots corresponding to video animations.

Videos examined in this study provide an opportunity to consider their adherence to Mayer and Moreno's(2002) seven principles of multimedia design. As a whole, many of Mayer and Moreno's principles were adopted in the TEDEd videos featured. In particular, animation was presented with narration, rather than with on-screen text (i.e., modality principle), and animations corresponded to the narrative information provided (e.g., temporal contiguity principle). At the same time, the coherence principle, requiring that all extraneous information be removed from narration, may have been violated, as may have the redundancy principle. The redundancy principle suggests that presenting animation and narration is preferable to the presentation of animation, narration, and on-screen text. This principle may have been violated in one of two ways. First, the videos featured in this study included a limited number of textual information, primarily having to do with numbers (e.g., 1%) within the animations depicted. For instance, in the penguin video, when different types of penguin species were discussed in the narration, these were labeled in the animations on the screen (e.g., Emperor, Royal). Second, participants had the option of turning on the closed captions accompanying each video, potentially resulting in the presentation of written text, alongside narration and animation. The extent to which such violations of the redundancy principle interfered with or supported comprehension and integration have yet to be determined. Moreover, additional work is needed to systematically manipulate video features to examine the differences in strategy use arising as a result of adherence to or violations of the principles developed by Mayer and Moreno (2002).

The two texts and videos used in this study were nested within the domain of biology and addressed the topic of species preservation. More work is needed to determine the extent to which the strategies identified in this study, associated with processing both text and video, function at a domain general or a domain specific level. Examining strategy use across both mediums and domains remains a next step in investigating the TSC.

The same questions were used to assess prior knowledge at pre-test and to assess comprehension after reading. At pre-test these questions were used to gauge students' general familiarity with the target topic, whereas, at post-test these questions were used to assess students' comprehension of information in texts. However, adopting such a methodological approach meant that pre-post learning scores could not be used in analyses. In the future, it may be necessary to disentangle students' familiarity with particular topics from their conceptual knowledge of these topics.

Additionally, findings in this study may have been underpowered. Specifically, post-hoc power analyses, conducted for comparing performance across conditions, determined that analyses ranged in power from only 0.087 to 0.372 (with $a = 0.05$). For us to have been able to recognize differences in overall integration performance, with 80% power, as is typically recommended, a sample of 230 students would have been required. As a result, the analyses in this study need to be replicated with a larger sample.

Finally, the present analyses compared video and text comprehension and integration. These two modalities were selected as they are commonly used media for delivering content to students; nevertheless, a more appropriate analog for understanding video comprehension may have been presenting students with an audio recording of video content sans animation. Future work should more systematically manipulate the audio and visual aspects of video to better understand their facilitative role in comprehension and integration. Moreover, the integration of information across more than two documents is an important area for future research.

5. Conclusion

This study examined students' strategic processing when comprehending and integrating information presented via two texts or two videos. Strategy use was found to be both similar and different across modalities of information presentation. Moreover, a variety of strategies, previously identified as supporting single text comprehension, were identified as also supporting both text and video integration. This suggests potential avenues for further fostering students' cross-source integration in the classroom. Nevertheless, performance did not differ across modalities of information presentation. As such, more work is needed to understand what types of content may best be presented through which modalities.

Appendix A. Penguin and turtle texts

The popularity, plight, and poop of penguins

Dyan deNapoli
TedEd: Lessons Worth Sharing.
Video: https://www.youtube.com/watch?v=kGhknFzrnXg.

Penguins have long captured the imagination and the hearts of people the world over. But while popular culture depicts them as clumsy, adorable birds with endlessly abundant populations, the truth is that penguins are exceedingly graceful, often ornery, and their populations are in rapid free fall.

Their real life situation is far more precarious than people think. And if current trends do not change, it may not be long before penguins can only be found in movies. There are many things about penguins that make them odd birds, so to speak.

For one thing, they are one of the few bird species that cannot fly, having evolved from flight-capable birds about 60 million years ago. Surprisingly, their closest living relative is the albatross, a bird known for its enormous wingspan and extraordinary soaring abilities. It may seem strange that losing the ability to fly would be an evolutionary advantage, but the penguin's short, flipper-like wings and solid bones allow them to swim faster and dive deeper than any other bird on Earth, filling an ecological niche that no other bird can.

Penguins inhabit the southern hemisphere, being one of the few bird species able to breed in the coldest environments. But contrary to popular belief, they are not restricted to cold regions nor are there any at the North Pole. In fact, only 4 of the 18 penguin species regularly live and breed in Antarctica. Most penguins live in subtemperate to temperate regions. And the Galapagos penguin even lives and breeds right near the equator off the coast of South America. They are also found in South Africa, Namibia, Australia, and New Zealand, as well as on a number of islands in the southern Atlantic, Pacific, Indian, and Antarctic Oceans.

Although penguins spend 75% of their lives at sea, they must come to shore every year to reproduce and to molt their feathers. They do this in a variety of places, from the temporary ice sheets of the Antarctic to the beaches of South Africa and Namibia, to the rocky shores of sub-antarctic islands, to the craggy lava surfaces in the Galapagos.

Different penguin species have different nesting practices. Some dig burrows into dirt, sand, or dried guano; some nest in tussock grasses; some build nests out of small rocks, sticks, and bones; while others don't build any nests at all. Although most penguins lay a clutch of two eggs, the two largest species, the King and the Emperor, lay a single egg that they incubate on top of their feet for approximately two months.

Unfortunately, 15 of the 18 penguin species are currently listed as threatened, near-threatened, or endangered by the International Union for Conservation of Nature. In the last several decades, we have seen the world populations of most penguin species decline by up to 90%, with two of them, the Yellow-eyed and Galapagos penguins, down to just a few thousand birds.

Penguins are an indicator species, the proverbial "canary in the coal mine." Simply put, if penguins are dying, it means our oceans are dying And sadly, most of this decline is attributable to human activities. Historically, penguins have had to deal with multiple disturbances. The mass collection of penguin eggs and the harvesting of the seabird guano they nested in caused the dramatic decline of several penguin species. If you're wondering what humans would want with seabird poop, it was used as an ingredient in fertilizer and in gunpowder, being so valuable that in the 19th century, it was known as white gold.

Current threats to penguins include the destruction of both marine and terrestrial habitats, introduced predators, entrapment in fishing nets, and pollution from plastics and chemicals. There have also been several large-scale oil spills over the past 50 years that have killed or impacted tens of thousands of penguins around the world.

But the two major threats to penguins today are global warming and overfishing. Global warming impacts penguins in multiple ways, from interrupting the production of krill due to decreased sea ice formation in the Antarctic, to increasing the frequency and severity of storms that destroy nests, to shifting the cold water currents carrying the penguins' prey too far away from penguin breeding and foraging grounds.

Even though humans may be the greatest threat to penguins, we are also their greatest hope. Many research and conservation projects are underway to protect penguin habitats and restore vulnerable populations. With a little help from us and some changes in the practices that impact our planet and oceans, there is hope that our tuxedo-clad friends will still be around in the next century.

The survival of the sea turtle

Scott Gass.
TED-Ed: Lessons Worth Sharing.
Video: https://www.youtube.com/watch?v=t-KmQ6pGxg4.
Sea turtles are miraculous.

First, they've been around since the late Jurassic, roughly 150 million years ago. Cohorts of the dinosaurs, sea turtles have survived through the challenges of eons, existing still today, where many others have ended their evolutionary run.

Second, throughout the centuries and up until today, every living adult sea turtle has overcome the odds, existing as a consequence of chance, skill, and capability.

The gauntlet each sea turtle faces in the course of its lifetime goes thus: First, deposited as a clutch of leathery, ping pong ball-sized eggs into a nesting pit dug by its mother high on the beach, of the 50 to 200 eggs laid, roughly 20 percent will never hatch.

Roughly a month and a half after having been laid, the surviving eggs hatch and the young turtles, each small enough to fit in the palm of your hand, squirm to the surface, emerging from the sand en-masse and making their desperate dash for the sea.

Along the way, debris, pitfalls, crabs, sea gulls, raccoons and other threats will claim roughly 50 percent of those who rose from the sand. For those that actually reach the surf, they trade one set of threats for another, as they first face the repelling force of the waves, and then find a whole new host of predators awaiting them: various fish, dolphins, sharks and sea birds, as the young turtles come to the surface for air.

For their first few days of life, should they count themselves amongst the living, the vulnerable turtles swim frantically forward. Ultimately, they will often look to settle in a patch of flotsam, preferably a patch of floating seaweed.

Now, for the next several months, they will seek to avoid those that would eat them, find that which they might eat themselves, and not fall to the pressures of challenging weather or unfortunate currents. In this phase, roughly 50 percent of those who reach the surf will perish.

Ultimately, with the passage of years, the survivors will increase in size, from that of a dinner plate at year one to that of a dinner table, in the case of one species at least, the Leatherback, a decade or so later. With size comes some measure of protection.

The only truly worrisome predators now are some of the larger shark species – bulls, tigers and whites – and the occasional killer whale. At approximately two decades of age, the survivors will be old enough themselves to breed, and continue the cycle which their very existence heralds.

Of those that began as eggs on a distant beach, now less than 10 percent remain. At least, those were the odds prior to significant human interference. Over the past century, and in particular in the last several decades, human endeavors, from beach development to plastic refuse to poaching, long lines, nets, and even noxious chemicals, including oil, have upped the ante for sea turtles, causing their survival rate to drop to around one percent or less from each nesting cycle.

It is this added human pressure which has pushed each of the eight sea turtle species to either a threatened or endangered state. For while they have evolved to overcome a host of obstacles, the most recent has arisen so quickly and at such scale that the species find themselves overwhelmed.

So let's quickly recap this cycle of odds, using a hypothetical nesting season, for females may nest multiple times in a single year, of 1000 eggs, for sake of ease. One thousand eggs laid. Eight hundred hatch. Four hundred make it to the water. Two hundred progress toward adulthood. Twenty survive to breeding age – that is, without human interference. Two survive to breeding age with human interference.

So a breeding adult sea turtle is the very embodiment of a longshot. It is the exception, not the rule. A jackpot. It is, in a very real sense, a miracle.

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