Scientific Studies of Reading

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/hssr20

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To cite this article: Reese Butterfuss, Panayiota Kendeou, Kristen L. McMaster, Elly Orcutt & Okan Bulut (2021): Question Timing, Language Comprehension, and Executive Function in Inferencing, Scientific Studies of Reading, DOI: 10.1080/10888438.2021.1901903

To link to this article: https://doi.org/10.1080/10888438.2021.1901903

Published online: 05 Apr 2021.

SCIENTIFIC STUDIES OF READING
https://doi.org/10.1080/10888438.2021.1901903

Question Timing, Language Comprehension, and Executive Function in Inferencing

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ABSTRACT

We examined the extent to which the timing of inferential questioning influenced kindergartners' inferencing performance in a non-reading context, while also taking into account individual differences in language comprehension and executive function. Students completed the eight-week Early Language Comprehension Individualized Instruction (ELCII) application by responding to audiovisual inferential questions administered in one of two timing conditions: either (1) during video watching at various points (*online*) or (2) after the video was finished (*offline*). Results suggest that online questioning fostered greater overall gains in inferencing skill from pretest to posttest. Moreover, students with higher executive function demonstrated greater gain in inferencing than students with lower executive function. Likewise, students with higher language comprehension skills demonstrated greater gains in inferencing than students with lower language comprehension skills. Theoretical and instructional implications of the findings and areas for future research are discussed.

Over one-third of US fourth-grade students' struggle to comprehend information they read (National Assessment of Educational Progress, 2019). Below-basic levels of comprehension in fourth grade result from a series of failures in early identification and remediation. Even prior to formal reading instruction in kindergarten, many students struggle to comprehend language. For these children to avoid difficulty in school – and everyday life – they must develop the foundational skills that support construction of meaning from language (Oakhill & Cain, 2012). A core skill in this context is inferencing (e.g., Kintsch, 1988). To draw an inference, one must generate or retrieve relevant information left implicit in a text (McNamara & Magliano, 2009). Inferencing is successful when learners reactivate and integrate previously acquired information with newly encoded information (Elbro & Buch-Iversen, 2013; Oakhill, 1984). Inferencing skills are critical to comprehension across both reading and non-reading contexts (Florit, Roch, & Levorato, 2011, 2014; Kendeou, Bohn-Gettler, White, & van den Broek, 2008; LARRC, Currie, & Muijselaar, 2019; Lepola, Lynch, Laakkonen, Silven, & Niemi, 2012). Specifically, drawing accurate inferences contributes to the construction of a coherent mental representation of what is read, which then fosters retrieval of information that was explicit or implicit in the text (e.g., Kintsch & van Dijk, 1978).

According to the Inferential Language Comprehension framework (iLC; Kendeou et al., 2019), inferencing skills can be evaluated and taught in non-reading contexts via inferential questioning that includes scaffolding and feedback, with the use of technology and dynamic visual narratives (i.e., videos). Thus, it is possible to target inferencing skills in students as early as kindergarten, before mastery of foundational reading skills. One key factor that may influence the effectiveness of

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inferential questioning is the timing with which they are posed. Specifically, questions can be posed *during* video viewing by interrupting the video when inferences are necessary for comprehension (i.e., online questioning). Alternatively, questions can be posed *after* video viewing (i.e., offline questioning), which eliminates interruptions to encoding. Furthermore, successful online and offline inferencing may differentially implicate students' language comprehension skills needed to construct mental representations of the information they encounter in the video. Additionally, executive function may be critical to managing the activation and integration of relevant information required to successfully draw inferences from video content.

In the current study, we examine the extent to which the timing of inferential questions (*online vs. offline*) influences gains in inferencing skill in the context of a web-based, individualized inferencing instruction for kindergartners called ELCII, while also accounting for students' language comprehension skills and executive function. We describe next the theoretical framework that has informed the development of ELCII, as well as competing hypotheses regarding the benefits of online and offline questioning.

The Inferential Language Comprehension Framework (iLC)

The iLC framework (Kendeou et al., 2019) is predicated on the idea that inferencing is necessary to derive meaning from language and construct a mental representation, regardless of whether the context is aural, visual, or both (e.g., Cohn, 2018; Cohn & Magliano, 2020; Magliano, Loschky, Clinton, & Larson, 2013). Indeed, there is evidence that inferencing is a *general* skill that is critical for comprehension across different media (Kendeou et al., 2008; Kendeou, van den Broek, White, & Lynch, 2009; van den Broek, Lorch, & Thurlow, 1996). iLC leverages this generality to propose that inferencing can be facilitated via questioning, scaffolding, and feedback in the context of different media. This is consistent with existing work that highlights a degree of overlap in the cognitive processes necessary to construct a mental representation of information across different media (Cohn, 2018).

In the context of iLC, inferencing is successful if: (1) the information that is necessary to draw the target inference is activated, and (2) the student integrates the information coherently with their evolving mental representation. The inference can then be validated by explanatory feedback that ensures the student understands why their inference was correct. By contrast, if drawing an inference is unsuccessful, either because of failure to activate or integrate the information (Elbro & Buch-Iversen, 2013), then immediate feedback explains why the inference is incorrect. In this case, providing students with scaffolding intended to facilitate (re)activation and integration of the target information can guide the learner to successfully make the correct inference during a second attempt.

The iLC framework served as the basis for the development of the Early Language Comprehension Individualized Instruction (ELCII), a web-based instructional application that leverages inferential questioning and scaffolding in the context of videos.

The Early Language Comprehension Individualized Instruction (ELCII) Application

ELCII provides instruction in inferencing in a non-reading context for kindergarten students in general education settings. ELCII includes 24 age-appropriate fiction and nonfiction instructional video modules (i.e., dynamic visual narratives) to train inferencing over eight weeks. Each module includes several components administered via an animated pedagogical agent and take 15–20 minutes to complete.

Each module begins with instruction of three academic vocabulary words critical to understanding the video. Each word is displayed onscreen with a picture that depicts its meaning in the video. The ELCII pedagogical agent (a) reads the word; (b) prompts the student to say the word; (c) provides a brief, child-friendly definition, and (d) uses the word in a sentence relevant to the video. Each video is approximately 5 minutes, is developmentally appropriate for kindergartners, and provides multiple opportunities for inference generation. Fiction videos include stories with a clear goal structure, multiple attempts to meet the goal(s), and a resolution. Nonfiction videos include informational descriptions about animals or natural phenomena.

A set of five inferential questions were developed for each video. Questions prompt *bridging* inferences (i.e., inferences that establish semantic relations between explicitly conveyed content) or *elaborative* inferences (i.e., inferences that integrate general knowledge related to the content into the mental model) that address coherence breaks in each video. Thus, the inferential questions generally require students to infer an implicit causal link. As such, the inferential questions comprise "why" and "how" questions (e.g., Graesser & Franklin, 1990).

ELCII presents the inferential questions using audio and pictures in a multiple-choice format, thereby eliminating decoding demands. Responses are automatically recorded and scored. For each correct response, ELCII provides feedback that includes a brief explanation for *why* the response is correct based on events in the video. For each incorrect response, ELCII provides scaffolding that presents relevant video contents a second time to reactivate information that is necessary to draw the inference for a second attempt at answering the question. Thus, students are able to leverage multiple presentations of rich visual and auditory information to support the target inference. After the second attempt, ELCII provides feedback that includes a brief explanation for *why* the response is correct or incorrect based on events in the video. A sample module with the basic functionality demonstrated can be viewed here.

Timing of inferential questions during inference instruction: competing hypotheses

One key factor that may influence the effectiveness of ELCII's inferential questioning is the *timing* with which questions are posed. Indeed, in the extant literature, there is variability with respect to whether inference tasks pose questions *during* encoding of the relevant information (i.e., *online*; e.g., LARRC, Currie, & Muijselaar, 2019; Florit et al., 2011, 2014) or *after* encoding of all information (i.e., *offline*; e.g., Lepola et al., 2012). Examining this issue in the context of a web-based instruction such as ELCII is critical, as online and offline inferential questions may differ in their benefits for comprehension of video contents and may place different demands on students' cognitive and language skills.

Online questioning

Online inferential questions may benefit comprehension because they prompt inferences at the points when they are needed for comprehension – namely, during coherence breaks (McMaster & Espin, 2017; McMaster et al., 2012). ELCII also provides feedback regarding the correctness of responses and, if incorrect, provides video-based scaffolding to that ensure information necessary to draw the inference is active. This timely feedback may further facilitate the construction of a coherent, rich mental representation (Beck, McKeown, Sandora, & Kucan, 1996).

Despite the potential benefits of online questions, one drawback is that they interrupt the video. Such interruptions by default also introduce coherence breaks that may compete for students' cognitive resources to maintain global coherence, especially for kindergartners who are still developing language comprehension skills (van den Broek, Tzeng, Risden, Trabasso, & Basche, 2001). Thus, the interruptions due to online questioning may place increased demands on students' executive function (EF), a family of top-down cognitive skills necessary for attention and control of thoughts or behavior (e.g., Diamond, 2013). In childhood, EF may be best conceptualized as a unitary construct that captures the skills involved in attention regulation and conscious goal-directed problem solving (Zelazo, Blair, & Willoughby, 2016). These skills include cognitive flexibility, working memory, and inhibitory control (e.g., Miyake et al., 2000).

Posing inferential questions online may place particularly high demands on working memory because students must selectively maintain activation of relevant information as a basis to draw the target inference (Fletcher & Bloom, 1988). Students who maintain relevant information in working memory over the course of the inferential question may also effectively reactivate important video content that was unfolding prior to the interruption, allowing them to pick up where they left off and therefore maintain the global coherence (Cain, Oakhill, & Bryant, 2004; Currie & Cain, 2015; Seigneuric & Ehrlich, 2005).

Moreover, online questioning implicates learners' ability to shift attention during encoding. Specifically, students must be able to flexibly shift attention from unfolding video contents to the inferential question, answer options, and corresponding feedback posed by pedagogical agent, then they must shift back to the video contents once the video resumes after the interruption (Cartwright, 2015). This may be especially important given that the coherence breaks inherent in online questions may disrupt the attentional scaffolds typically afforded by videos (Hutson, Smith, Magliano, & Loschky, 2017; Smith, 2012). This is especially true for students who respond incorrectly to the inferential question at the first attempt, who then receive scaffolding and a second attempt and therefore face an even longer disruption. Finally, students must be able to inhibit irrelevant information from dominating their mental representation, as well as suppress environmental distractions from interfering with task performance (e.g., De Beni & Palladino, 2000). These processes may be even more demanding in the context of online questioning given that much of the information students encode from the video may be irrelevant to drawing the target inferences, and therefore must be suppressed (cf. McNamara & McDaniel, 2004). Overall, students with higher EF may demonstrate better performance on ELCII's online questions than their lower-EF counterparts.

Offline questioning

In contrast to online questioning, posing ELCII's inferential questions offline may benefit comprehension because offline questions allow for continuous, uninterrupted encoding of the video content. This continuous encoding may allow students to concentrate their limited processing resources exclusively to understanding video content.

At the same time, a potential drawback of offline questioning is the requirement that students had constructed a coherent mental representation during encoding as a basis to draw the target inferences. Offline questions by default cannot support the coherence of students' evolving mental representations. This means that students are left to draw the target inferences on the basis of their own understanding, without prompting or feedback at critical points (e.g., during coherence breaks). Thus, the coherence of their mental representation of the video contents depends heavily on their language comprehension skills.

Language comprehension refers to students' ability to understand main ideas, remember details, recall event sequences, and interpret beyond the explicit information (Wiig, Semel, & Secord, 2003). These processes rely on the orchestration of several skills (Kim, 2015, 2016). In particular, Kim (2015) found that two core linguistic skills, vocabulary knowledge and syntactic knowledge, directly contributed to kindergarten students' listening comprehension performance. Existing research has suggested a reciprocal relation between inferencing skill and language comprehension skills (Lepola et al., 2012).

We anticipate that offline questioning will place increased demands on language comprehension skills because it leaves students to negotiate coherence breaks on their own, without the assistance prompted by online inferential questions, feedback, and scaffolding. Therefore, eliciting inferences after the completion of the video requires students to retrieve information from their mental representation of the video and integrate that information to draw the target inferences. The extent to which students retrieve relevant information to draw the target inference largely depends on the quality of the mental representation they constructed during encoding. Thus, in the ELCII offline condition, students with high language comprehension skills may perform better compared to their lower-language comprehension counterparts.

The present study

In the present study, we examine the extent to which the timing of inferential questioning in a web-based instruction (i.e., ELCII) influences students' inferencing performance, while also taking into account individual differences in language comprehension and executive function. Drawing on the extant literature, we hypothesize that online and offline questioning place different demands on students' language and cognitive skills. Online inferential questions capitalize on students' evolving mental representations to elicit the target inferences when coherence breaks arise during video viewing. At the same time, online questions inherently impose interruptions in processing, which may compete for cognitive resources and place greater demands on students' EF. By contrast, offline inferential questions do not impose interruptions in comprehension. However, offline questions require that learners already constructed a coherent mental representation, placing greater demands on their language comprehension skills.

Identifying the conditions (online vs. offline) and for whom (individual differences in EF and language comprehension) a web-based instruction such as ELCII improves inference skill is important for both theory and practice. From a theory standpoint, the findings have the potential to advance our understanding of how affordances of media in web-based environments interact with individual differences to influence comprehension. This understanding can contribute to further theory building, for example refine the principles of the iLC Framework that informed the design of ELCII. From a practical standpoint, the findings can inform further refinement of the ELCII instruction and learning environment and identify for whom online or offline questioning would be optimal.

Method

Participants

Data were collected in the context of a larger project to develop and examine the usability and feasibility of ELCII web-based instruction for developing kindergartners' inferencing skills. One-hundred thirty-nine kindergarten students (82 boys; Pretest M_{age} = 5.62, SD_{age} = .28) across two schools in a Midwest suburban school district completed ELCII. Participants were ethnically diverse (40% White, 37% Hispanic, 12% Black, 7% Asian, 2% Native American), economically diverse (60% Free/Reduced Lunch Eligible), and linguistically diverse in terms of reported home language (58% English, 32% Spanish, 10% other). Also, 15% of students in the sample received special education services. Students were randomly assigned individually to either the online (n = 71) or offline (n = 68) ELCII condition. Due to missing scores on the language comprehension measure (n = 9) or the MIA posttest (n = 1), data from n = 10 students were not included in all analyses, resulting in a final sample of n = 129 students (n = 65 online; n = 64 offline). Characteristics of the students in the online and offline conditions were comparable and mirrored the overall sample in terms of race, home language, age, grade, and gender.

Measures

Language comprehension

Students completed the Understanding Spoken Paragraphs (USP) subtest of CELF-5 (Wiig et al., 2003) to assess language comprehension. The CELF-5-USP requires students to listen to brief passages and answer questions and gauges students' ability to (1) sustain attention while listening to spoken paragraphs of increasing length and complexity; (2) construct meaning from spoken narratives; (3) interpret beyond the given information; and (4) respond to questions about the texts (Wiig et al., 2003). The questions probe for understanding of main ideas, memory of facts and details, event sequences, and generating inferences and predictions. Responses are scored as correct or incorrect according to response norms. Students' scale scores were used in analyses. Twenty-five percent of responses were rescored for interrater reliability, which was acceptable (Kappa = .80, p < .001). All discrepancies were resolved through discussion. Internal consistency for the 20 items on the ages 5– 6 form in this sample was α = .86. Of the 20 items, 9 are inferential (α = .71) and 11 are non-inferential (α = .85).

Executive function (EF)

Students completed the Minnesota Executive Function Scale (MEFS; Carlson & Zelazo, 2014), a web-based sorting task in which the sorting criteria change across blocks of trials. MEFS derives an EF total score that reflects the student's ability to maintain task goals, update sorting criteria, resist distraction, and flexibly shift attention among multiple task dimensions. The MEFS total score (range: 0– 100) takes into account accuracy and response time for each trial using a proprietary algorithm (Reflection Sciences, 2017). The reliability between students' scores for the two different sorting criteria was acceptable (ICC = .76).

Inferencing

Students completed the Minnesota Inference Assessment (MIA; Kendeou et al., 2020) to evaluate gains in inferencing performance. MIA includes two equivalent, parallel forms, one administered at pretest and the other at posttest. Each form consists of two videos – one fiction and one nonfiction – each approximately 5 min in length and was accompanied by eight multiple-choice inferential questions. Questions were posed by a pedagogical agent. Each form was administered to students in the same condition as the ELCII instruction, either online or offline. In the online condition of MIA, the inferential questions interrupted the video at the point at which those inferences were necessary for comprehension, whereas in the offline condition those same questions appeared after students finished watching the video. For each question, there were four possible answer options presented audio-visually. Participants responded to each question via touchscreen selection (see Table 1 for examples).

Students' responses to the MIA items were analyzed using Item Response Theory (IRT). Theta scores (θ) from the Rasch model were estimated and used in subsequent analyses. Theta scores consider both students' ability and the difficulty of the items and therefore provide more precise information about students' inferencing performance than a traditional sum score. Higher theta scores indicate better performance. Reliability estimates obtained from the Rasch model based on the marginal reliability method (Thissen & Wainer, 2001) were adequate given the length of each condition: Pretest form was $\overline{\rho}$ = .71 in the online condition and $\overline{\rho}$ = .72 in the offline condition; posttest form was $\overline{\rho}$ = .74 in the online condition and $\overline{\rho}$ =.74 in the offline condition.

To evaluate the measurement equivalence of the online and offline forms, both item analysis within the Classical Test Theory framework and test-level analysis within the IRT framework were used. The results of item analysis indicated that difficulty (i.e., proportion-correct) and discrimination (i.e., point-biserial correlations) of the items were similar between the online and offline forms. Furthermore, the test information function (TIF) derived from the Rasch model – which is a measure of the amount of information provided by the item responses across a particular range of ability – suggested that the online and offline forms provided a similar level of information across the same range of ability levels (θ = −4 to θ = 4). The more information a test provides at a given ability level, the higher the measurement precision. The inverse of TIF provides conditional standard error of measurement (CSEM), which indicates the level of measurement error at a given ability level. The CSEM results also indicated that the forms had a similar distribution of measurement error across the ability levels. Overall, these analyses suggest that the online and offline MIA forms are equivalent in terms of content, item characteristics, and measurement precision, and thus can be directly compared at pre- and posttest.

ELCII pedagogical agent and instructional application

Students completed the study over the course of 10 weeks. Weeks 1 and 10 included MIA pretest and posttest forms. Weeks 2– 9 consisted of three *ELCII Instruction* modules per week (24 total). Half of the modules included a 5-minute fiction video (*Shaun the Sheep/Berenstain Bears*) and half included a

Table 1. Example items from each form (pretest and posttest).

	Question Stem	Response Choices
Pretest Form		
Blinky Bill – Granny's Glasses	[After breaking Granny's glasses] Blinky tried to take Old Wombat's glasses because he thought:	(A) *Granny could use them to read stories* (B) Granny might like that style better (C) Wombat could afford a new pair (D) Wombat didn't need them while sleeping
Bald Eagles	Bald eagles need to be able to go for long periods of time without eating because:	(A) *Finding food in the wild is hard* (B) Salmon don't spawn often (C) Finding food is dangerous (D) Other birds steal their food
Posttest Form		
Blinky Bill – Apple Thieves	The dad asked his son to stand back [from an electric fence] because he:	(A) *Didn't want him to get shocked* (B) Thought he saw the apple thief (C) Needed space to set the trap (D) Didn't need help anymore
Cephalopods	The octopus cannot eat crabs without their hard beak because:	(A) The octopus doesn't like to eat living crabs (B) *The crabs have hard shells and claws* (C) There is a lot of prey in the ocean (D) The secret weapon makes the prey taste better

Correct answer options are italicized.

5-minute nonfiction video (nature documentaries). The introduction to the first ELCII module presents a brief, age-appropriate conceptualization of inferencing to the student (i.e., "to make an inference, we connect something we see, hear, or read to something we already know to make a brand-new idea") and then provides a real-life example. Each module included five multiple-choice inferential questions in either the online or offline conditions.

The questions required students to connect newly encoded information with information presently previously within the video episode to draw an inference. Each question consisted of four answer options; in addition to the correct answer, three distractor options were constructed such that there were two plausible, yet incorrect answers that included information from the current episode and one implausible answer that included information that was not mentioned. The questions were the same in the online and offline conditions.

In both conditions, if students answered a question incorrectly, ELCII (*the pedagogical agent*) provided feedback and scaffolding before a second attempt. The feedback told the student that their choice was incorrect and explained why. The scaffolding required the student to re-watch two important parts from the video that served to reactivate the information necessary to draw the target inference. These important parts from the video lasted several seconds and were presented in the order in which they originally appeared in the episode. After the scaffolding, the question was presented a second time, along with the four answer options. If the students' second attempt was incorrect, ELCII provided the correct answer and explanation for the correct inference. See the Appendix for an example ELCII questioning sequence.

Procedure

First, parental consent and student assent were obtained prior to data collection. Then, all students completed the assessments over three testing sessions totaling approximately 90 minutes. The first session included the CELF-5-USP and MEFS. Students were tested in a quiet room outside of their general education classroom. In a subsequent session, the MIA pretest form was administered individually using Chromebooks in students' classrooms. Students then completed 24 ELCII instructional modules over eight weeks (three modules per week), followed by the MIA posttest form. All assessments were administered by trained research staff. To ensure reliable task administration and scoring, administrators were trained to mastery (90% accuracy) on CELF-5-USP and obtained required certification for MEFS prior to administration. All study procedures were approved by the University of Minnesota Institutional Review Board and comply with US Federal Policy for the Protection of Human Subjects.

Results

First, we examined whether random assignment resulted in group equivalence between the two conditions. We conducted independent-samples *t*-tests with EF (MEFS total score), language comprehension (CELF-5-USP scaled scores), and MIA pretest theta scores as dependent variables. As Table 2 shows, students in the online and offline conditions did not differ on MEFS, $t(149) = .30$, $p = .94$, CELF-5-USP, $t(138) = .33$, $p = .42$, or MIA, $t(137) = -1.16$, $p = .39$.

To examine the effects of ELCII questioning condition (online vs. offline) on inference performance from pretest to posttest, we conducted a mixed-effects ANOVA with time (pre vs. post) as a within-subjects factor, questioning condition as a between-subjects factor, and MIA theta scores as the dependent variable. This analysis was conducted twice, with the addition of language comprehension or EF, respectively, as a continuous predictor.[1] For all analyses, the effect sizes are described in accordance with the conventions proposed by Richardson (2011).

The results of the first mixed-effects ANOVA that included language comprehension as a continuous predictor revealed a small-to-medium effect of time, $F(1, 126) = 5.96$, $p = .016$, = .045, such that students demonstrated gains in inferencing skill from pretest ($M = -.95$, $SE = .07$) to posttest ($M =$

Table 2. Descriptive statistics for all measures.

	Online				Offline			
Measure	M	SD	Min	Max	M	SD	Min	Max
MIA Pretest	−1.07	.79	−3.63	.58	−.90	.85	−2.08	1.21
CELF-5-USP	7.94	3.09	3	15	7.83	2.89	3	16
MEFS	47.36	14.14	8	89	47.15	13.69	15	91

MIA = Minnesota Inference Assessment; CELF-5-USP = Clinical Evaluation of Language Fundamentals-5th Edition-Understanding Spoken Paragraphs Scaled Score; MEFS = Minnesota Executive Function Scale Total Score.

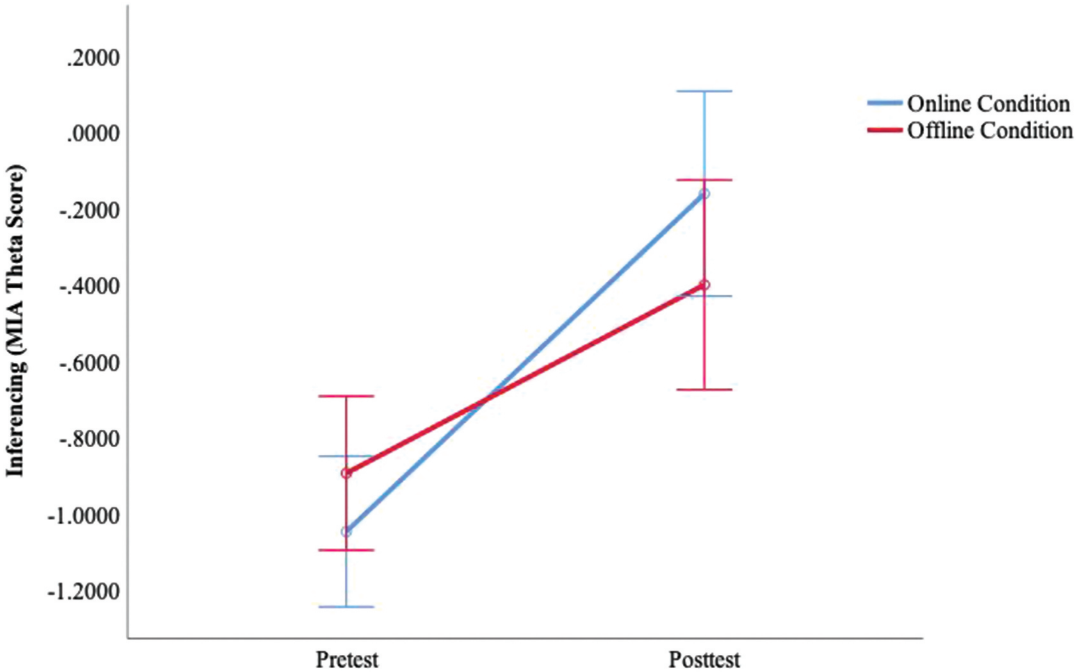

Figure 1. Gains in inferencing performance from pretest to posttest for the online and offline ELCII conditions.

−.21, *SE* = .09). This effect was qualified by a small-to-medium time x condition interaction, $F(1, 126) = 4.82$, $p = .030$, = .037, such that students in the online condition demonstrated greater gains from pretest to posttest than students in the offline condition (see Figure 1).

There was also a large effect of language comprehension, $F(1, 125) = 38.79$, $p < .001$, = .24, such that students with higher language comprehension skills demonstrated better inferencing overall than students with lower language comprehension skills. This effect was qualified by a large time x language comprehension interaction, $F(1, 125) = 31.57$, $p < .001$, = .20, such that students with higher language comprehension skills demonstrated greater gains in inferencing from pretest to posttest than students with lower language comprehension skills (see Figure 2). The condition x language comprehension interaction did not approach significance, $F(1, 125) = .044$, $p = .834$. These findings may be driven, in part, by the language comprehension measure including inferential items (i.e., inferencing predicting inferencing). To rule out this alternative explanation, we also conducted the analysis with the CELF-5-USP sum score that included performance on only the 11 non-inferential items. The results are consistent with those for the CELF-5-USP scaled score that includes the full set of items. Namely, there is a main effect of language comprehension, $F(1, 125) = 40.93$, $p < .001$, = .25, as well as a time x language comprehension interaction, $F(1, 125) = 38.43$, $p < .001$, = .24, such that students with higher language comprehension skills demonstrated greater gains in inferencing skill than did students with lower language comprehension skills.

The results of the second mixed-effects ANOVA that included EF as a continuous predictor revealed a small-to-medium effect of time, $F(1, 132) = 5.48$, $p = .021$, = .040, and a small-to-medium time x condition interaction, $F(1, 126) = 4.25$, $p = .041$, = .031 (see Figure 1). Results also showed a large effect of EF, $F(1, 132) = 16.00$, $p < .001$, = .11, such that students with higher EF demonstrated better inferencing overall than students with lower EF. This effect was qualified by a large time x EF interaction, $F(1, 130) = 20.26$, $p < .001$, = .13, such that students with higher EF demonstrated greater

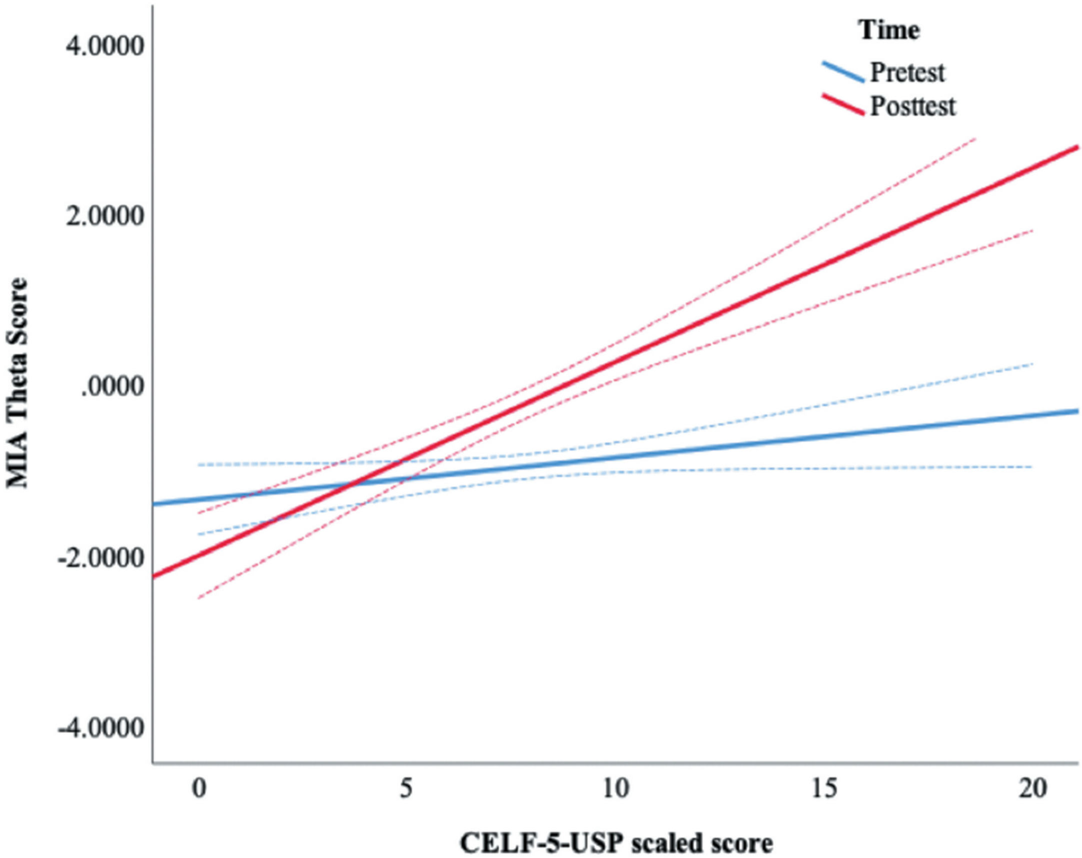

Figure 2. Relations between language comprehension skills and gains in inferencing performance from pretest to posttest.

gains in inferencing skill from pretest to posttest than students with lower EF (see Figure 3). Finally, the condition x EF interaction did not approach significance, $F(1, 131) = 1.20$, $p = .28$.

One potential concern about comparing effects of ELCII instruction across the online and offline conditions is that students in the online condition had slightly lower MIA pretest scores than did students in the offline condition. Even though this difference was not significant, the means suggest that students in the online condition had slightly more room for growth. To address this concern, we conducted two mixed-effects ANOVAs that controlled for MIA pretest scores. These analyses included condition (online vs. offline) as a between-subjects factor, language comprehension or EF, respectively, as a continuous predictor, pretest inferencing performance (MIA pretest theta scores) as a covariate, and posttest inferencing performance (MIA posttest theta scores) as the dependent variable.

For the first analysis, the results showed a large main effect of language comprehension, $F(1, 125) = 52.0$, $p < .001$, = .29, a large main effect of MIA pretest inferencing performance, $F(1, 125) = 15.27$, $p < .001$, = .12, and a small-to-medium main effect of condition, $F(1, 125) = 3.88$, $p = .051$, = .030, such that MIA posttest inferencing performance was higher for students in the online ($M = -.045$, $SE = .12$) than the offline ($M = -.37$, $SE = .12$) condition. For the second analysis, the results showed a large main effect of EF, $F(1, 131) = 26.18$, $p < .001$, = .17, a large main effect of MIA pretest inferencing performance, $F(1, 131) = 24.43$, $p < .001$, = .16, and a small marginal effect of condition, $F(1, 131) = 3.19$, $p = .076$, = .024, such that MIA posttest inferencing performance was higher for students in the online condition ($M = -.12$, $SE = .13$) than the offline ($M = -.44$, $SE = .13$) condition. Taken together these analyses show that the superior performance of students in the online condition was present even after controlling for pretest inferencing performance.

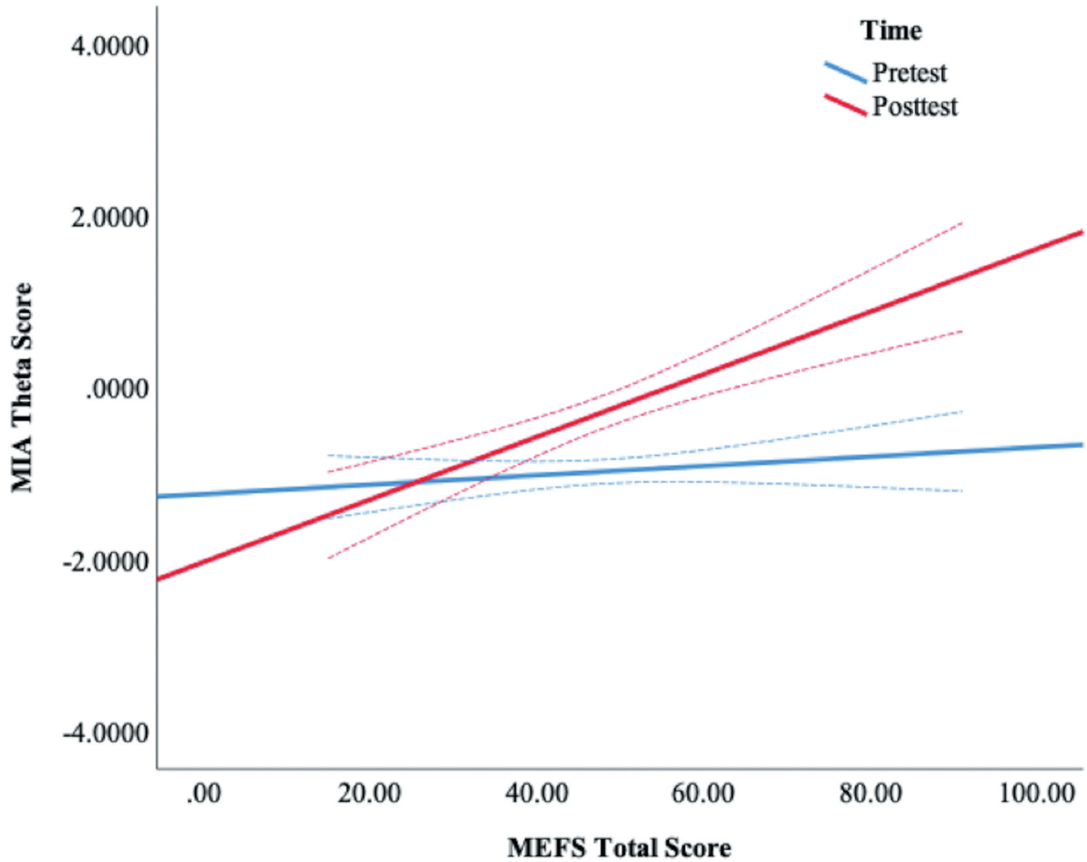

Figure 3. Relations between executive function and gains in inferencing skill from pretest to posttest.

Discussion

In the present study, we examined the extent to which the timing of inferential questioning in the web-based ELCII instruction (online vs. offline) influenced kindergartners' inferencing performance, while also taking into account individual differences in language comprehension and EF. Online inferential questions elicited the target inferences when coherence breaks arise during video comprehension, but they were hypothesized to place greater demands on students' EF due to the frequent interruptions. By contrast, offline inferential questions did not interrupt comprehension, but they were hypothesized to place greater demands on students' language comprehension skills because they required that students had constructed a coherent mental representation of the video.

Overall, the current findings suggest that students in both the online and offline conditions demonstrated gains in inferencing from pretest to posttest as a function of the eight-week ELCII instruction. However, students in the online condition demonstrated greater gains than their counterparts in the offline condition. This finding suggests that prompting students to draw inferences *during* encoding of video content at the specific points when those inferences were necessary for comprehension provided greater benefit for students' inferencing skill compared to posing those same questions *after* encoding of the videos. Offline questioning, by contrast, does not support the construction of students' evolving mental representations, but instead requires that students constructed a coherent mental representation of the information during encoding with minimal support. These findings are consistent with those in the extant literature of aural book-reading interventions highlighting the important role of language comprehension skills in inference generation (Davies, McGillion, Rowland, & Matthews, 2020) as well as the add-on benefit of online questioning interventions, especially for younger students (Freed & Cain, 2017).

These findings also extend prior work by providing evidence for the mechanisms that underlie the relative effectiveness of online and offline audiovisual inferential questions, feedback, and scaffolding (as hypothesized in iLC, Kendeou et al., 2019). Namely, the results suggest that eliciting inferences when information is still active in working memory provides added benefit for inferencing skill. It is possible that the online question itself fosters *validation* of information that is likely already activated (O'Brien & Cook, 2016), which in turn allows students to more efficiently integrate the information to draw the target inference. Because relevant information is already activated by online questioning, incorrect responses more likely reflect a failure in *integration* than in activation. Thus, online feedback and scaffolding may only need to target the integration of activated information. By contrast, offline inferential questions require that students retrieve video content that is no longer active. This means that incorrect responses could reflect failures in activation *and/or* integration. Thus, because the question itself may not cue retrieval of relevant information, the offline scaffolding and feedback must first serve to reactivate relevant information, which still must be integrated in order to draw the inference for the second attempt. Importantly, these potential mechanisms appeared to have unfolded more effectively for students with higher language comprehension skills and EF.

With respect to language comprehension, and contrary to our hypothesis, students with higher language comprehension skills showed greater gains in inferencing than their lower-language comprehension counterparts, regardless of whether they were in the online or offline condition. Thus, students who are more skilled at sustaining attention while listening to spoken paragraphs, constructing meaning from spoken narratives and text, and interpreting beyond the given information (Wiig et al., 2003) benefited more from ELCII. This finding suggests that the online and offline questioning conditions may be relatively aligned in terms of their language comprehension demands. Indeed, regardless of condition, students are required to draw the same target inferences in response to the same coherence breaks in the ELCII videos. Thus, students with stronger language comprehension skills are better able to draw these inferences (Carlson & Zelazo, 2014; Davies et al., 2020), regardless of when they are elicited. That is, in the online condition, students with strong language comprehension may be more capable of integrating active video contents to draw the target inferences while still maintaining global coherence of their mental representation. In the offline condition, students with strong language comprehension may have constructed more coherent mental representations from which to retrieve information in response to ELCII's questions.

With respect to EF, and contrary to our hypothesis, students with higher EF demonstrated greater benefit from ELCII than students with lower EF, regardless of whether they were in the online or offline condition. Across both conditions, students who are more skilled at maintaining relevant information and task goals in working memory, suppressing irrelevant information and inappropriate responding, and shifting attention among different discourse and task elements are more likely to demonstrate greater gains in inferencing from ELCII. This finding suggests that the online and offline questioning conditions may pose comparable demands on EF. Regardless of when questions were posed, students had to manage coherence breaks and attention (e.g., Hutson et al., 2017) and reduce the activation of irrelevant information to construct a coherent mental representation (Cain, 2006; De Beni & Palladino, 2000; Kieffer, Vukovic, & Berry, 2013). Thus, in the online condition, students with higher EF may have prevented irrelevant information from drawing activation away from the information required to answer the inferential questions. In the offline condition, students with higher EF may have reduced retrieval interference from irrelevant information as they responded to the questions. Moreover, students also had to update information in working memory as each answer option and/or scaffolding video clip was presented and suppress irrelevant information (i.e., incorrect response options) in the face of several options from which to choose (Diamond, 2013).

Moreover, EF is closely tied to students' skill in planning to meet a goal (Cartwright, 2009). Students with strong planning skills may be more apt at monitoring their mental representations as they unfold and may also flexibly adopt different strategies to achieve a more coherent understanding of the text (Cartwright, 2015; Nouwens, Groen, Kleemans, & Verhoeven, 2021). Thus, students with higher EF may have been better equipped to respond to the inferential questions as a function of overcoming irrelevant information and adapting their comprehension strategies to increase coherence, regardless of the timing.

Future work in the context of ELCII and similar web-based interventions (e.g., iSTART-Early; McNamara, Levinstein, & Boonthum, 2004) must examine several factors that were not addressed in the current work. Namely, future work must consider the extent to which the need for feedback and scaffolding differs across online and offline questioning. It is possible that students more often require scaffolding in the offline condition as a function of retrieval failure during questioning. More information about the role of feedback and scaffolding in online and offline questioning would further inform our understanding of the mechanisms of inferencing instruction and future development of interventions. Additionally, subsequent work must examine the role of video genres in inferencing performance. It could be the case that greater knowledge demands of nonfiction material (e.g., Afflerbach, 1990; LAARC, Currie, & Muijselaar, 2019) could differentially influence students' gains in inferencing skill in the context of ELCII's online and offline questions.

Critically, future work must examine the extent to which the online and offline versions of ELCII predict later reading comprehension performance, given that the ultimate goal is for the inferencing skills developed in the context of ELCII to transfer to reading contexts. Even though the current study suggests that online inferential questioning may foster greater overall gains in inferencing skills, it is unknown whether online or offline questioning would foster greater transfer and thus gains in later reading comprehension relative to a control condition. In this context, transfer could be targeted using teacher-led read-aloud modules in which students listen to stories and respond verbally to inferential questions, either during or after reading.

Finally, it is important to acknowledge that the current findings suggest that the "rich get richer" – students with higher language comprehension and EF skills demonstrate greater gains in inferencing than their lower-skill counterparts after receiving ELCII. Such "Matthew Effects" have long been observed in the context of literacy instruction (e.g., Stanovich, 1986; Walberg & Tsai, 1983). Matthew Effects are often attributed to differential exposure to reading material and reading practice (Stanovich, 1986). However, we find it unlikely that students who demonstrated fewer gains in inferencing skill had less exposure to or experience with dynamic visual narratives (videos) than students who demonstrated greater gains, as students tend to be familiar with videos by Kindergarten (Pagani, Fitzpatrick, & Barnett, 2013). However, it is plausible that kindergartners with stronger language comprehension skill and EF were better equipped to meet the processing demands of the ELCII's modules, which in turn produced a cumulative advantage over the duration of ELCII.

Ultimately, the goal of ELCII is to increase inferencing skills for students who are likely to struggle and experience subsequent difficulty in reading comprehension. To address these disparities in skill gains, future development of ELCII could include additional scaffolding, vocabulary instruction, and more practice opportunities to provide further support for students who demonstrate relative task underperformance over the course of ELCII instruction.

Note

1. 1 The sample size allowed us to conduct two separate, parallel analyses to examine the relation between EF and language comprehension on gains in inferencing skill. However, reporting separate models precludes direct comparison of whether EF or language comprehension is the stronger predictor of gains in inferencing skill. To explore this issue, we conducted an analogous mixed ANOVA that included both CELF scaled scores and MEFS total score as continuous predictors. With respect to language comprehension, the results revealed a large main effect of language comprehension, $F(1, 125) = 29.60$, $p < .001$, $\bar{\rho} = .173$, such that scores were overall higher for students with higher CELF-5-USP scores. These main effects were qualified by a large time x language comprehension interaction, $F(1, 125) = 16.80$, $p < .001$, = .118. With respect to EF, there was also a small-to-medium time x EF interaction, $F(1, 125) = 4.47$, $p = .037$, = .034. The main effect of EF did not reach significance ($F = 0.84$, $p =$

.36). It is apparent from these results that language comprehension is a stronger predictor of gains in inferencing skill than is EF; however, these results should be interpreted with caution, as including both language comprehension and EF in the model simultaneously reduces statistical power.

Acknowledgments

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Disclosure statement

The authors have no conflicts of interest to disclose.

Funding

This research is supported by grants R324A160064 and R305A170242 from the U.S. Department of Education to the University of Minnesota, grants R305A180144, R305A190063, and R305A180261, from the U.S. Department of Education to Arizona State University, and grant N00014-19-1-2424 from the U.S. Office of Naval Research to Arizona State University.

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Appendix. ELCII Questioning Sequence Example

(a) Vocabulary (b) Video

(c) Inferential Question (d) Scaffolding and Feedback

(e) Modeling Inference Making