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Does Online Comprehension Monitoring Make a Unique Contribution to Reading Comprehension in Beginning Readers? Evidence from eye movements

Young-Suk Grace Kim[a], Christian Vorstius[b], and Ralph Radach[b]

[a]University of California, Irvine; [b]University of Wuppertal

ABSTRACT
The goal of this study was to investigate the nature of online comprehension monitoring, its predictors, and its relation to reading comprehension. Questions were concerned with (a) beginning readers' sensitivity to inconsistencies, (b) predictors of online comprehension monitoring, and (c) the relation of online comprehension monitoring to reading comprehension over and above word reading and listening comprehension. Using eye tracking technology, online comprehension monitoring was measured as the amount of time spent rereading target implausible words and looking back at surrounding contexts. Results from 319 second graders revealed that children spent greater time fixating on inconsistent than consistent words and engaged in more frequent lookbacks. Comprehension monitoring was explained by both word reading and listening comprehension. However, comprehension monitoring did not uniquely predict reading comprehension after accounting for word reading and listening comprehension. These results provide insight into the nature of comprehension monitoring and its role in reading comprehension for beginning readers.

Reading comprehension involves complex processes, including many language, cognitive, and print-related skills. According to the simple view of reading (Hoover & Gough, 1990), this complexity can be captured by two essential skills, language comprehension and word reading (Catts, Adlof, & Ellis Weismer, 2006; Joshi, Tao, Aaron, & Quiroz, 2012; Kim, 2011; see Florit & Cain, 2011, for a review). Word reading involves a complex set of skills such as phonological, orthographic, and semantic processing (Adams, 1990; Carlisle, 2004; Kim, Apel, & Al Otaiba, 2013; Nagy, Berninger, Abbott, Vaughan, & Vermeulen, 2003; Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004), and comprehension involves an even more complex set of language and cognitive skills (e.g., Cain, Oakhill, & Bryant, 2004; Kendeou, Bohn-Gettler, White, & Van Den Broek, 2008, 2015, 2016, 2017; Perfetti, Landi, & Oakhill, 2007).

Comprehension monitoring is one such higher order cognitive process involved in comprehension. It refers to evaluating, regulating, and reflecting on constructed meaning (Baker, 1985; Oakhill & Cain, 2012) and recognizing comprehension failures (Wagoner, 1983). Successful comprehension requires establishing an accurate situation model, which, in turn, relies on a series of construction and integration processes (Graesser, Singer, & Trabasso, 1994; Kintsch, 1988; Zwaan & Radvansky, 1998). Comprehenders first have to construct initial, elementary propositions based on textual information and then update and integrate propositions across the text and with one's background knowledge. Comprehension monitoring is hypothesized to play a critical role during the integration process, as initial local propositions have to be evaluated for accuracy and consistency and then have to be corrected via integration processes to establish a coherent and accurate situation model (Kim,

CONTACT Young-Suk Grace Kim kim.youngster@gmail.com; young.kim@uci.edu School of Education, University of California, Education Building, Office 3455, Irvine, CA 92697

2015, 2016). In other words, comprehension monitoring contributes to the evaluation and repair processes during comprehension, and, therefore, lack of comprehension monitoring would lead to an inaccurate situation model.

Comprehension monitoring has been extensively investigated using an inconsistency detection framework (i.e., the ability to detect violation of consistency in a sentence or text; Baker, 1984; Beal, 1990; Cain et al., 2004; Kim & Phillips, 2014) and has been shown to be important to text comprehension. Much previous work on comprehension monitoring has been conducted in the context of reading (e.g., Cain & Oakhill, 2006; Cain et al., 2004; Oakhill & Cain, 2012; Vosniadou, Pearson, & Rogers, 1988; Yuill & Oakhill, 1991). Another line of work also indicates (a) that there is large variation in comprehension monitoring in oral language contexts, even for young children (Baker, 1984; Kim, 2015, 2016, 2017; Kim & Phillips, 2014; Revelle, Wellman, & Karabenick, 1985; Skarakis-Doyle, 2002), and (b) that individual differences in comprehension monitoring are related to comprehension of oral texts (i.e., listening comprehension; Kim, 2016, 2017; Kim & Phillips, 2014). Furthermore, an intervention improved comprehension monitoring in an oral language context for prekindergartners from low socio-economic backgrounds (Kim & Phillips, 2016).

In the present study our goal was to expand our understanding of comprehension monitoring and its role in reading by examining *online* comprehension monitoring for beginning readers (i.e., second graders). The aforementioned previous work on comprehension monitoring used tasks that demanded a deliberate effort to find anomalies in text by asking children whether they notice any inconsistencies in the read or heard sentences. In contrast, we used eye tracking methodology to measure online comprehension monitoring because eye movements can capture moment-to-moment processes in a natural reading context, without drawing the child's attention to the existence of inconsistencies in the text.

Eye movement research in the last four decades has revealed a great deal of information about online processes during reading (see Radach & Kennedy, 2004; Rayner, 2009; Rayner & Kliegl, 2012; for recent reviews). A number of parameters are available as indicators of underlying processes. For example, first-pass reading time, or the summed duration of all fixations within a word or region, before the first saccade leaves that region, is thought of as an indicator of lexical access or decoding (Rayner, 1998). On the other hand, rereading time, or the time spent on a word after first-pass reading, reflects higher order processes such as syntactic integration and construction of a situational model (Raney, Campbell, & Bovee, 2014; Rayner, Pollatsek, Ashby, & Clifton, 2012). In principle, longer rereading times can be a result of either more regressions or longer fixation times following (the equivalent amount of) regressions. Bicknell and Levy (2011) suggest that higher level linguistic processing causes the reader to go back and reread previous text in order to correct a failure in or decreased confidence in comprehension. Eye-tracking technology is an excellent tool to capture online comprehension monitoring in normal reading conditions without invoking any possibility about the presence of inconsistencies in the given text, which was the case in previous studies where participants were asked to identify inconsistencies (e.g., Baker, 1984; Cain et al., 2004; Kim, 2017). When using eye tracking technology, time spent rereading target words and surrounding regions would likely indicate the reader's identification of semantic inconsistencies and possible repair attempts. Indeed, some previous studies focusing on sentence and discourse processing provide evidence that in skilled adult readers, higher order comprehension processes influence eye movements primarily when problems such as syntactic ambiguity occur (e.g., Binder, Duffy, & Rayner, 2001; Clifton, Staub, & Rayner, 2007; Rayner, Garrod, & Perfetti, 1992), resulting in longer fixation durations, shorter saccades, and more regressions.

Research with children and eye tracking has gained momentum over the last decade after some pioneering work in the 1990s (Blythe et al., 2006; Blythe & Joseph, 2011; Häikiö, Bertram, Hyönä, & Niemi, 2009; Huestegge, Radach, Corbic, & Huestegge, 2009; Joseph, Nation, & Liversedge, 2013; Krieber et al., 2017; McConkie et al., 1991; Vorstius, Radach, Mayer, & Lonigan, 2013; Vorstius, Radach, & Lonigan, 2014; see also Was, Sansosti, & Morris, 2017). There is little dispute that, with development, readers show decreases in sentence reading times, fixation durations, number of fixations, refixations, and regressions, and increases in saccade amplitudes and word skipping probability. However, studies that examine higher level processing and relations to off-line assessments of reading skills are still scarce. A recent study by Krieber et al. (2017) is an exception and showed relations between eye movements and off-line reading skills for 22 German adolescent readers. Another study examined fifth-grade students' comprehension monitoring by focusing on the processing of conjunctive relations between clauses (Vorstius et al., 2013). In this study, students read sentences that contained either consistent or inconsistent information (e.g., *Erica blushed because she was nervous.* [consistent]; *Erica blushed because she was confident.* [inconsistent]). Fifth graders were sensitive to inconsistency such that they spent substantially greater amounts of time in the target word region of inconsistency. Moreover, readers at all skill levels were able to identify the inconsistencies, as evidenced by prolonged first-pass reading times. However, children with better reading skill showed more rereading of critical sentence regions, indicating an association between reading skill and comprehension monitoring. Other work with children in upper elementary grades (i.e., fifth and sixth grades) has provided similar results when the inconsistency occurred in semantic relations across sentences (Connor et al., 2014) or in an extended narrative text (van der Schoot, Reijntes, & Van Lieshout, 2012).

Present study

Prior work has revealed that comprehension monitoring is an important skill that contributes to text comprehension (both listening and reading; Cain et al., 2004; Kim, 2015, 2016; Kim & Phillips, 2014; Strasser & Del Río, 2014; Vosniadou et al., 1988). Building on these previous studies, we aimed to expand our understanding about comprehension monitoring and its unique role in reading comprehension, using data at the beginning of second grade and eye tracking methodology. Three specific primary research questions guided the present study. First, are beginning readers sensitive to inconsistencies in written texts? The vast majority of previous work, particularly those with eye tracking, included children in upper elementary grades (Grades 5 or 6) who have achieved basic reading skills and consequently, our knowledge is extremely limited about online comprehension monitoring for beginning readers whose reading is largely constrained by decoding skills. An exception is a study with Finnish-speaking first graders which found that beginning readers in Finland do monitor their comprehension, and good comprehenders showed more consistent rereading and lookbacks (Kinnunen, Vauras, & Niemi, 1998).

In the present study, we examined the amount of time spent on target implausible words (word N) and adjacent words (word N + 1 and word N + 2), as indicated by first-pass reading (decoding) and rereading (as part of comprehension monitoring). We also examined the extent to which children went back to the sentence that contained target words (sentence 4) and to the preceding sentences (sentences 1–3), after having read target implausible words (i.e., inconsistent sentences). These lookbacks (i.e., time spent rereading the sentence that contains target implausible words and the preceding sentences) are important indicators of efforts to reinspect, repair, and resolve inconsistency. We anticipated substantially greater reading times on target implausible words and adjacent words, as well as increased lookbacks, when readers need to determine semantic inconsistency.

If beginning readers engage in, and individual differences are found in, online comprehension monitoring, an important corollary is what explains variation in this behavior. This was our second research question. In particular, we examined whether word reading and listening comprehension are related to comprehension monitoring. Word reading was expected to contribute to comprehension monitoring because comprehension monitoring was measured in the context of written texts (i.e., reading context). For beginning readers, increased reading time and reinspection (or lookbacks) would reflect not only comprehension monitoring but also level of word reading proficiency to some extent. If this is the case, comprehension monitoring (as measured by increased rereading times on inconsistent words, lookbacks to disambiguating regions of text, and subsequent rereading) would be negatively related to word reading proficiency to the extent that it is influenced by word reading proficiency. Furthermore, listening comprehension might contribute to comprehension monitoring after parsing out the effect of word reading. Mounting evidence indicates that listening comprehension, a discourse-level oral comprehension skill, involves lower level oral language skills, such as vocabulary and grammatical knowledge, as well as higher order processes such as monitoring and inference (Florit, Roch, & Levorato, 2014; Kim, 2015, 2016, 2017; Kim & Phillips, 2014; Lepola, Lynch, Laakkonen, Silvén, & Niemi, 2012; Tompkins, Guo, & Justice, 2013). In other words, although decoding skill would place a constraint on beginning readers' monitoring behavior as expressed in eye movements, individual differences in listening comprehension—the ability to comprehend oral language at the discourse level—may also contribute to online comprehension monitoring over and above word reading, even for beginning readers.

The final question was whether online comprehension monitoring makes a unique, independent contribution to reading comprehension after accounting for the two powerful component skills of reading comprehension, namely word reading and listening comprehension, according to the simple view of reading (see Figure 2). By now, the essential roles of word reading and listening comprehension in reading comprehension are well established (Catts et al., 2006; Joshi et al., 2012; see Florit & Cain, 2011, for a review). In fact, recent studies that measured word reading and listening comprehension as latent variables, with minimal measurement error, explained the vast majority of variance in reading comprehension (Adlof, Catts, & Little, 2006; Kim, 2017; Kim, Wagner, & Foster, 2011; Language and Reading Research Consortium [LARRC], 2015). Then, does comprehension monitoring, measured as online monitoring behavior using eye tracking methodology, contribute to reading comprehension over and above word reading and listening comprehension? To our knowledge, no previous studies have examined whether online comprehension monitoring behavior, or time spent looking at implausible target words and reinspecting the sentence that contains the implausible words, makes an additional contribution to reading comprehension over and above word reading and listening comprehension. Note that word reading in the simple view of reading is the ability to read or decode individual words out of context; thus, it was measured as such in the present study as well as in previous studies.

Method

Participants

The present study draws on data from 319 second-grade children (50% girls; M_{age} = 7.33 years, SD = .52) in six schools in the southeastern region of the United States. These children were participants in a larger longitudinal study about reading development from Grades 1 to 3 (see Kim & Petscher, 2016, for a study on word prosody using data in Grade 1), but data from the beginning of second grade are utilized because this is when comprehension monitoring using eye tracking technology was assessed. Data from four children were excluded from the analysis because they did not follow instructions/could not read, showed random viewing patterns, or could not answer simple comprehension questions (see next). Approximately 61% of the children were White, 25% were African American, 6% were Hispanic, 6% were multiracial, and 3% were Asian American. Only two children were classified as having limited English proficiency. Approximately 53% of the children were eligible for free and reduced-price lunch. According to the school district record, approximately 14% of the children received speech services, and 2% of the children received services related to language impairment and learning disabilities.

Measures

Comprehension monitoring

Materials. Children were presented with short stories consisting of four sentences, with each sentence presented as one line of text. Items were constructed so that the first sentence provided an opening statement with general background information. The second sentence presented a key statement with one critical concept specifying a specific sematic relation such as an object, time, instrument, or attribute. The third sentence served as a filler, intended to increase working memory load, which fit the context but had no direct relationship to the statements made before. Critically, the final sentence continued the action or situation described in sentence 2, such that the argument of the critical sematic relation was either consistent or inconsistent with the one used in sentence 2. For example, when the initial statement (sentence 2) read, "He always wears his shorts to play outside," the critical continuation (sentence 4) would be "This morning, Danny put on his shorts/pants and went outside." Note that the last sentence is in both versions (shorts or pants) correct by itself. However, to detect an inconsistency in the case of the "pants" version, the reader needs to be sensitive to the fact that the most recent object was not consistent with the one seen before, indicating monitoring for coherence in the accumulating semantic representation on the story level (see Rinck, Gamez, Diaz, & De Vega, 2003, for a similar approach for adults; see Appendix A for sample consistent and inconsistent stories).

Twenty-one stories were presented to children, including one practice story, 10 stories with consistent information, and 10 stories with inconsistent information. Two counterbalanced lists were created such that the consistent and inconsistent versions of each item were read by different participants. When creating the items, priority was given to variations in the semantic (in)consistency over the lexical properties of the target word such as word length and frequency. This resulted in slight differences in word properties for the target word N, as well as words N + 1 and N + 2. Mean word lengths and frequencies (SubtLEXus) for consistent versus inconsistent words are presented in Table 1. Note that words in the inconsistent condition were, on average, shorter and had higher frequency values than words in the consistent condition. As shorter words and words with higher frequencies generally receive shorter viewing times (countering our hypothesized effect), any effect indicating longer times on the inconsistent words would make the case for an inconsistency effect even stronger.

To promote reading for meaning, children were asked five simple recall questions after randomly selected stories (e.g., What is the boy's name?). Questions were never related to the inconsistencies, and responses to these questions were not included in the analysis because they were not intended to capture individual differences in deep processing of meaning but rather to ensure reading for meaning.

Apparatus and procedure. Texts were presented on a 21-in. monitor with a screen resolution of 1024 × 768 pixels. Courier New font in 20-point size was used, and viewing distance was adjusted so that one letter corresponded to .33 degree of visual angle. Texts were presented in black color on a gray background with double line spacing. Each short story for the inconsistency detection task was presented on a separate screen. Children were instructed to "read the text silently, so that you understand the content and are able to answer comprehension questions." Before the child read a story, the recording system was calibrated to ensure optimal measurement accuracy using a 9-point calibration and validation routine. Immediately prior to text presentation, an additional drift correction check was performed to ensure identical start positions for the eyes during the onset of each story. If deviations larger than .5 degree of visual angle were detected, the camera system was

Table 1. Descriptive Word Properties: Mean Word Length (Letters) and Word Frequency (SubtLEXus lg10WF) for Consistent and Inconsistent Sentences

		Word Length		Word Frequency	
Region	Condition	*M*	*SD*	*M*	*SD*
Word N	Consistent	6.0	0.9	2.6	0.8
	Inconsistent	5.2	1.4	3.1	0.9
Word N + 1	Consistent	4.5	2.4	4.9	0.8
	Inconsistent	3.4	1.7	4.9	1.1
Word N + 2	Consistent	4.1	1.2	4.7	0.9
	Inconsistent	3.0	0.9	5.6	0.9

recalibrated. Eye movements were tracked with an EyeLink1000 desktop-mounted system with 500 Hz sampling rate. Viewing and recording were binocular, but only data from the right eye were included in data analysis. Eye-movement data were processed using custom build EyeMap software (Tang, Reilly, & Vorstius, 2012) and SPSS.

Eye movement variables. For the current study we focused on two temporal eye-movement parameters: first-pass reading time (gaze duration) and rereading time on three words in sentence 4, namely, the target word (N) as well as the word immediately following the target word (N + 1) and the second next word (N + 2). We examined words N + 1 and N + 2 separately in addition to word N in order to capture possible spillover effects from the target word (Kliegl, Nuthmann, & Engbert, 2006). First-pass reading time was calculated by summing up all durations of fixations on a respective word before leaving the word for the first time. Rereading time for each word was calculated by summing up all durations of fixations on the respective word after first-pass reading; therefore, words that were fixated on in first-pass reading but were not reread were assigned a rereading time of zero. As laid out earlier, first-pass reading time and rereading time are indicators of different ongoing processes, namely, decoding (first-pass reading time) and later integration processes, which are both relevant to comprehension monitoring (see Inhoff & Radach, 1998).

In addition to these word-based measures, we included sentence-level parameters to capture children's extended monitoring behavior after encountering the inconsistency by calculating the time spent on sentence 4 (in which the inconsistent word occurred) after first encountering the inconsistency. The same measure was also calculated for sentences 1–3, combining fixations on these preceding lines of text, as not all children looked back to all preceding sentences (see next). As accumulated viewing times on these sentences after first encountering the inconsistency reflect efforts to confirm and/or solve the inconsistency, we included 0s in the calculation of means for these parameters. Hence, along with cases where actual rereading took place, cases with no rereading were represented in the means of these sentence-level parameters.

Word reading. The following three tasks were used to measure word reading: the Letter Word Identification subtask of the Woodcock-Johnson III (WJ; Woodcock, McGrew, & Mather, 2001), the Word Reading subtask of the Wechsler Individual Achievement Test–III (WIAT; Wechsler, 2009), and the Sight Word Efficiency subtask of the Test of Word Reading Efficiency–II (TOWRE; Wagner, Torgesen, & Rashotte, 2012). In these tasks, the child was asked to read aloud (isolated) words of increasing difficulty. The first two tasks were untimed, whereas TOWRE was a timed task (45 s). Cronbach's alpha estimates were .95 and .91 for the WJ Letter Word Identification and WIAT Word Reading tasks, respectively. Test–retest reliability for the TOWRE task was reported as .93 for 6- to 7-year-olds (Wagner et al., 2012).

Listening comprehension. Two tasks were used: the Listening Comprehension Scale of the Oral and Written Language Scales–II (OWLS; Carrow-Woolfolk, 2011) and the Oral Comprehension subtest of the WJ (Woodcock et al., 2001). In the OWLS Listening Comprehension task, the child was asked to point to the picture that best describes the heard sentences and connected texts (e.g., short stories). In the WJ Oral Comprehension subtest, the child was asked to complete the heard sentences (e.g., People sit in ______) and short paragraphs. Cronbach's alpha estimates were .93 and .74 for the OWLS Listening Comprehension and WJ Oral Comprehension tasks, respectively.

Reading comprehension. The following two tasks were used: the Passage Comprehension subtest of the WJ and Reading Comprehension subtest of the WIAT. The Passage Comprehension subtest is a cloze task where the child was asked to read sentences and short passages and fill in blanks. In the Reading Comprehension subtest, the child was asked to read passages and answer multiple-choice questions. Cronbach's alpha estimates were .86 and .87 for the WJ Passage Comprehension and WIAT Reading Comprehension tasks, respectively.

Procedures

Language and reading assessment

Children were individually assessed in quiet spaces in several sessions in the fall. Assessors were rigorously trained and had to meet 99% reliability in a fidelity check before they were allowed to work with children.

Data analysis

To address the question about whether beginning readers detect inconsistencies, we compared consistent and inconsistent stories with respect to reading times separately for three words of interest in sentence 4, namely, the target word (N), word N + 1, and word N + 2. In addition, we compared sentence reading times (for sentence 4 and sentences 1–3) after encountering the focal words of interest. Repeated measures analyses of variance with the factor, consistency, were used for statistical testing.[1]

Raw data from the eye tracker were transformed into csv-files using EyeMap (Tang et al., 2012). These files were then read into SPSS and cleaned. From a total of 353,416 fixations from 319 participants, 14,765 fixations were located on words N, N + 1, and N + 2 combined. Fixations shorter than 80 ms (2.3%) or longer than 2,000 ms (0.1%) were excluded from further analyses. Participants that contributed fewer than 20 trials (or items) were also eliminated from further analyses (19 participants, with a total of 237 fixations on target words; 1.7%), resulting in a final set of 14,528 fixations for word-based analyses and 339,686 overall fixations.

Before fitting structural equation models (SEMs) for the second and third research questions, eye-movement variables were log transformed due to slight skewness (see Table 3; also see Appendix B for an example[2]). Furthermore, measurement models were fitted to create the following latent variables: comprehension monitoring, word reading, listening comprehension, and reading comprehension.

To address the second research question, word reading and listening comprehension were hypothesized to predict comprehension monitoring (Figure 1). To address the third research question, two models were fitted. In the first model, word reading and listening comprehension were included as predictors of reading comprehension to examine the simple view of reading. In the second model, comprehension monitoring was added to examine its unique contribution over and above word reading and listening comprehension. Following conventions in the field, model fit was evaluated by widely used multiple indices, including the comparative fit index (CFI; > .90 as acceptable), Tucker–Lewis index (TLI; > .90 as acceptable), and root mean square error of approximation (RMSEA) and standardized root mean square residual (SRMR; < .10 as acceptable; Hooper, Coughlan, & Mullen, 2008; Hu & Bentler, 1999; Kline, 2013).

Results

Descriptive statistics and preliminary results

Table 2 presents descriptive statistics for listening comprehension, word reading, and reading comprehension measures. Mean standard scores of the language and reading skills indicate that children's mean performance is in the average range on all the measures compared to that of a norm group. For instance, the mean standard score for the OWLS Listening Comprehension was 106.60 (SD = 13.12) and for the WIAT Reading Comprehension was 100.36 (SD = 14.18).

[1]Note that using linear mixed effects models yielded identical results.

[2]Log transformed values are not particularly different from the original raw values for rereading time for target implausible word N, word N + 1, and word N + 2 (see Table 3). This is primarily due to the zero values as shown in Appendix B. Given that the 0s were true values, the results reported in the text are from data including 0s.

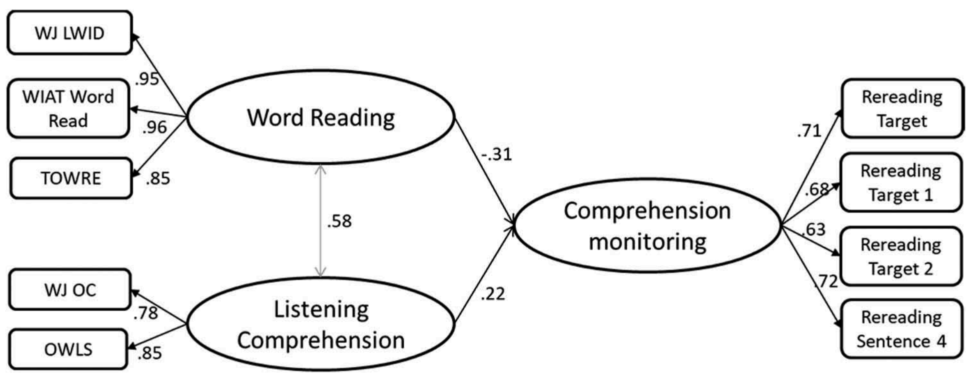

Figure 1. Standardized path regression weights of the model in which comprehension monitoring is predicted by word reading and listening comprehension. *Note*. Dark lines represent statistically significant relations. Gray lines represent covariances. WJ = Woodcock-Johnson III; LWID = Letter Word Identification; WIAT = Wechsler Individual Achievement Test–III; TOWRE = Test of Word Reading Efficiency–II; OC = Oral Comprehension; OWLS = Oral and Written Language Scales–II; Target = target inconsistent words.

Table 2. Descriptive Statistics for Listening Comprehension, Word Reading, and Reading Comprehension

Variable	*M*	*SD*	Minimum	Maximum	Skewness	Kurtosis
Listening Comprehension						
WJ Oral Comprehension	16.31	3.57	6.00	26.00	−0.03	−0.12
WJ Oral Comprehension SS	106.00	12.71	71.00	140.00	−0.16	−0.21
OWLS Listening Comprehension	83.75	11.68	46.00	111.00	−0.35	0.38
OWLS Listening Comprehension SS	106.60	13.12	65.00	135.00	−0.47	0.35
Word Reading						
WJ Letter Word Identification	41.94	6.62	24.00	62.00	0.20	0.44
WJ Letter Word Identification SS	108.58	12.08	73.00	135.00	−0.61	0.29
WIAT Word Reading	28.10	10.51	2.00	56.00	−0.04	−0.04
WIAT Word Reading SS	103.36	15.26	63.00	143.00	−0.37	−0.23
TOWRE Sight Word	51.82	13.52	4.00	80.00	−0.55	−0.20
TOWRE Sight Word SS	103.96	16.57	55.00	137.00	−0.59	−0.26
Reading Comprehension						
WJ Passage Comprehension	22.76	4.79	12.00	35.00	−0.03	−0.62
WJ Passage Comprehension SS	100.18	11.94	60.00	126.00	−0.53	0.22
WIAT Reading Comprehension	25.58	8.63	0.00	40.00	−0.57	−0.39
WIAT Reading Comprehension SS	100.36	14.18	46.00	149.00	−0.07	0.91

Note. WJ = Woodcock-Johnson III; SS = standard score; OWLS = Oral and Written Language Scales–II; WIAT = Wechsler Individual Achievement Test–III; TOWRE = Test of Word Reading Efficiency–II.

Research Question 1: Are beginning readers sensitive to inconsistencies in written texts?

For the analysis of sensitivity to inconsistencies, descriptive statistics for first-pass reading times and rereading times (Table 3) for different regions are presented. For first-pass reading times (i.e., gaze duration), we found an inconsistency effect, with longer reading times (+ 99 ms) on the inconsistent compared to consistent target word (word N), $F(1, 299) = 42.21$, $p < .001$. On the word immediately following the target word (word N + 1), the difference in first-pass reading times between consistent and inconsistent conditions was 15 ms and was not statistically significant, $F(1, 299) = 1.93$, $p = .17$. On the second word following the target word (word N + 2), we found a reversed inconsistency effect for first-pass reading (– 70 ms), $F(1, 299) = 44.57$, $p < .001$, which we attribute to the word properties (see Table 1), as words in the inconsistent condition were shorter and more frequent compared to those in the consistent condition.

With respect to rereading times, target words received significantly longer rereading fixations (+ 251 ms) in the inconsistent compared to consistent condition, $F(1, 299) = 106.81$, $p < .001$. The same

Table 3. Eye Movement Measures: Mean First-Pass Times and Rereading Times (ms) for Key Regions in Consistent and Inconsistent Target Sentences

Region	Condition	*M*	*SD*	Minimum	Maximum	Skewness	Kurtosis
First-pass times (gaze duration)							
Word N	Consistent	508	218	181	1522	1.51	3.12
	Inconsistent	607	290	223	2233	1.73	4.78
	Inconsistent log	6.31	.43	5.41	7.71	.33	−.14
Word N + 1	Consistent	471	184	163	1327	1.24	2.05
	Inconsistent	486	211	197	1908	1.92	7.43
	Inconsistent log	6.11	.39	5.28	7.55	.32	.07
Word N + 2	Consistent	499	175	166	1281	1.11	1.63
	Inconsistent	429	163	144	1309	1.35	3.09
	Inconsistent log	5.99	.36	4.97	7.18	.20	−.05
Rereading times							
Word N	Consistent	315	292	0	1780	2.10	5.37
	Inconsistent	566	479	0	3738	2.46	10.87
	Inconsistent log	5.93	1.18	0	8.23	−2.56	10.63
Word N + 1	Consistent	259	242	0	2014	2.41	10.62
	Inconsistent	351	328	0	3065	3.20	19.24
	Inconsistent log	5.36	1.34	0	8.03	−2.15	6.35
Word N + 2	Consistent	269	254	0	1532	2.33	7.53
	Inconsistent	324	248	0	1612	1.70	4.82
	Inconsistent log	5.29	1.47	0	7.39	−2.53	6.75
Sentence 4	Consistent	1516	774	377	7174	2.99	15.56
	Inconsistent	1811	854	341	6399	1.60	4.46
	Inconsistent log	7.40	.46	5.83	8.76	−.31	.92
Sentences 1–3	Consistent	1591	3000	0	31612	4.92	37.02
	Inconsistent	1741	3051	0	29728	4.61	31.66
	Inconsistent log	5.60	2.92	0	10.30	−1.02	−.20

Note. Total reading times for sentences include only fixation durations that occurred after the target word was fixated on and do not include viewing times on words N, N + 1, and N + 2. log = log transformation.

pattern was found for word N + 1 (+ 92 ms), $F(1, 299) = 28.91$, $p < .001$, and word N + 2 (+ 55 ms), $F(1, 299) = 13.78$, $p < .001$. It is important to note here that these elevated rereading times occurred despite the fact that words in the inconsistent condition were shorter and had higher frequency and, thus, were expected to be easier to process compared to the consistent counterparts.

Regarding rereading of sentences after encountering the target word, we found that rereading times for sentence 4 were significantly higher (+ 295 ms) in inconsistent compared to consistent stories, $F(1, 299) = 67.18$, $p < .001$. No significant difference was found for rereading times on sentences 1–3 after encountering the target word, $F(1, 299) = 2.09$, $p = .15$.

Note that there was a slight floor effect in the rereading time on sentences 1–3 such that, out of 300 children, 61 (20% of the sample) did not spend any time at all on the first three sentences (i.e., no reinspections of sentences 1–3).

Additional analyses showed that rereading behavior did not change as a function of time on task. This was an important manipulation check, as item construction was very similar across the task. However, this did not seem to have an influence on children's rereading behavior, at least not across the 20 trials (or items) used in this study. To further examine how children allocated their time when rereading, we performed scan path analyses for all fixations after encountering the target word region. Visual comparison of the results revealed that children in second grade do not yet show a stable, clear scanning pattern. Instead, we found full rereading, partial rereading, backward scanning, and sometimes even random scanning across and within children.

Overall, the data indicate that second graders at the beginning of the academic year are able to detect inconsistencies in short stories, although their scanning pattern is not clearly established yet, and that their efforts to resolve such inconsistencies are mostly restricted to the text region where the inconsistency was elicited. In this region, additional processing indicative of comprehension monitoring continues while fixating on the following word, creating a substantial total effect.

Research Question 2: Are word reading and listening comprehension related to comprehension monitoring?

Prior to fitting SEMs, latent variables were created for the following constructs: word reading, listening comprehension, reading comprehension, and comprehension monitoring using variables described above. Loadings were all adequate, ranging from .62 to .96 (*p*s < .001; see Figures 1 and 2). Comprehension monitoring was indicated by rereading time for target word N, target word N + 1, target word N + 2, and sentence 4 in inconsistent stories. The loading for the rereading time on sentences 1–3 was low (.15, p = .01), most likely due to the floor effect; therefore, it was not included as an indicator of comprehension monitoring in subsequent SEMs (the results were essentially identical when it was retained). Finally, confirmatory factor analysis was conducted to examine whether gaze duration (which is hypothesized to primarily tap into decoding processes) and rereading time for target word N, target word N + 1, target word N + 2, and sentence 4 (which are hypothesized to tap into comprehension monitoring) are best described as two dissociable latent variables or a single latent variable. Results showed that the two-factor model was superior ($\Delta\chi$ = 119.81, Δdf = 1, p < .001), and, therefore, in the subsequent structural models, rereading times were used as indicators of comprehension monitoring.

Bivariate correlations between rereading time indicators, listening comprehension, word reading, and reading comprehension are reported in Table 4. Rereading time indicators were moderately related to one another (.41 ≤ *r*s ≤ .50). Relations between listening comprehension, word reading, and reading comprehension ranged from moderate to strong (.35 ≤ *r*s ≤ .91). Relations of rereading

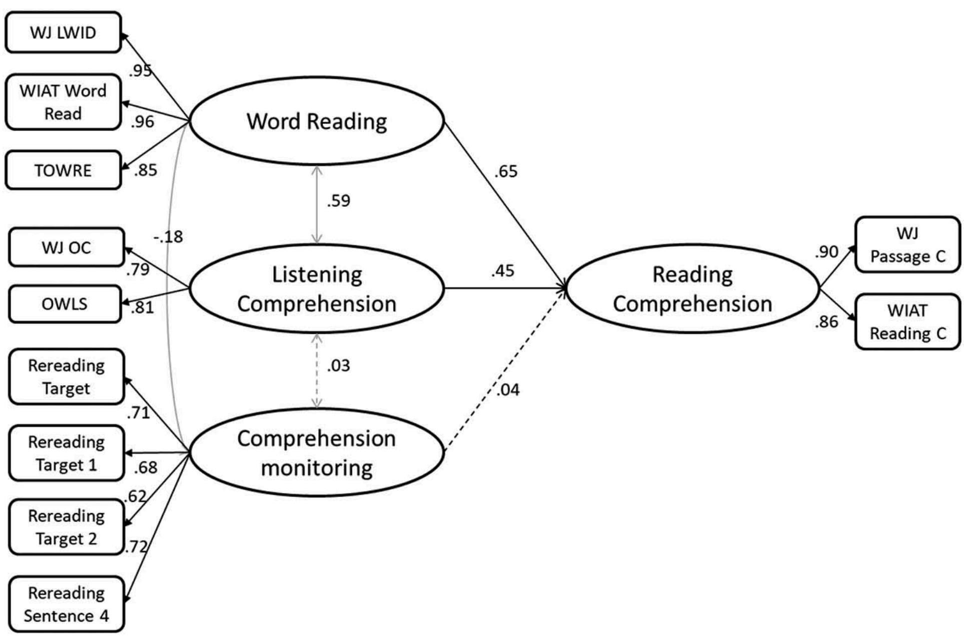

Figure 2. Standardized path regression weights of the model in which reading comprehension is predicted by word reading, listening comprehension, and comprehension monitoring. *Note*. Solid lines represent statistically significant relations. Dashed lines represent statistically non-significant relations. Gray lines represent covariances. WJ = Woodcock-Johnson III; LWID = Letter Word Identification; WIAT = Wechsler Individual Achievement Test–III; TOWRE = Test of Word Reading Efficiency–II; OC = Oral Comprehension; OWLS = Oral and Written Language Scales–II; Target = target inconsistent words; C = Comprehension.

Table 4. Bivariate Correlations Between Rereading Times (Transformed Values), Listening Comprehension, Word Reading, and Reading Comprehension

	1	2	3	4	5	6	7	8	9	10
1. Reread duration word N	1									
2. Reread duration word N + 1	.50***	1								
3. Reread duration word N + 2	.44***	.41***	1							
4. Reread of sentence 4 after reading target region	.48***	.44***	.45***	1						
5. WJ Oral Comprehension	0.05	0.07	−0.02	−.15**	1					
6. OWLS Listening Comprehension	0.11	0.10	0.07	−0.06	.64***	1				
7. WJ Letter Word Identification	0.03	−0.07	−0.04	−.30***	.44***	.48***	1			
8. WIAT Word Reading	0.00	−0.07	−0.04	−.30***	.41***	.44***	.91***	1		
9. TOWRE Sight Word Efficiency	−0.10	−.19**	−.12*	−.44***	.35***	.38***	.80***	.81***	1	
10. WJ Passage Comprehension	0.04	0.00	−0.01	−.20***	.59***	.63***	.70***	.72***	.66***	1
11. WIAT Reading Comprehension	0.06	−0.01	0.01	−.23***	.56***	.56***	.80***	.79***	.72***	.77***

Note. WJ = Woodcock-Johnson III; OWLS = Oral and Written Language Scales–II; WIAT = Wechsler Individual Achievement Test–III; TOWRE = Test of Word Reading Efficiency–II.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

times with listening comprehension, word reading, and reading comprehension ranged from null to moderate ($.00 \leq rs \leq .44$).

The SEM model had an adequate fit to the data, χ^2 (24) = 106.62, $p < .01$, CFI = .95, TLI = .92, RMSEA = .10, SRMR = .08; results are shown in Figure 1. Word reading was moderately and negatively related to online comprehension monitoring ($\beta = -.31$, $p < .001$), suggesting that children with lower word reading proficiency spent greater time rereading target words and the sentence containing target words (i.e., sentence 4). Once word reading was held constant, listening comprehension was positively related to online comprehension monitoring ($\beta = .22$, $p = .01$).

Research Question 3: Is comprehension monitoring related to reading comprehension after accounting for word reading and listening comprehension?

When reading comprehension was predicted by word reading and listening comprehension (i.e., simple view of reading), model fit was excellent, χ^2 (11) = 31.94, $p < .001$, CFI = .99, TLI = .98, RMSEA = .08, SRMR = .02. Word reading ($\beta = .64$, $p < .001$) and listening comprehension ($\beta = .46$, $p < .001$) were both independently related to reading comprehension and explained a total of 96% of variance in reading comprehension. When comprehension monitoring was included as an additional predictor, the model fit was good, χ^2 (38) = 137.35, $p < .01$, CFI = .96, TLI = .94, RMSEA = .09, SRMR = .08. However, after accounting for word reading and listening comprehension, online comprehension monitoring was not related to reading comprehension[3] ($\beta = .04$, $p = .29$; see Figure 2).

Discussion

Our goal was to investigate the nature and variability of online comprehension monitoring, its predictors, and its relation to reading comprehension for beginning readers. We found that second graders at the beginning of the school year were sensitive to inconsistencies in short stories such that they spent greater time rereading implausible target words than control words. These results are in line with previous studies with older children (e.g., Connor et al., 2014; van der Schoot et al., 2012) and highlight that such monitoring processes are in place early in reading development, which is consistent with an earlier study of online comprehension monitoring in Finnish first graders (Kinnunen et al., 1998). Furthermore, children, on average, spent more time looking back at the sentence that contained an implausible target word (sentence 4) than the prior sentences (sentences

[3]Results were essentially the same when the gaze duration latent variable was included as an additional predictor—neither gaze duration nor comprehension monitoring (rereading times) were statistically significant ($ps \geq .41$).

1–3). Lookbacks to preceding sentences were not found for quite a few children (20%), and, for many others, occurred only a couple of times, on average. Furthermore, lookbacks to preceding sentences had a weak relation to comprehension monitoring (i.e., weak loading), and post hoc analysis revealed that lookbacks to preceding sentences were not related to word reading or reading comprehension in bivariate correlations ($.00 \leq rs \leq .04$). These results suggest that at this early stage of reading development, lookbacks to previous text may be an indicator of a more deliberate strategy to resolve inconsistencies over and above the mechanism of detecting them.

In the structural analyses, as hypothesized, word reading proficiency was negatively related to comprehension monitoring such that low reading skill is associated with increased time spent rereading text. This indicates that time spent rereading and lookbacks captures not only comprehension-related processes but also decoding-related processes to some extent, at least for beginning readers (i.e., second graders). Important to note, though, when this constraining role of word reading was accounted for, listening comprehension was positively related to comprehension monitoring (Figure 1). This result is in line with a previous study, in which an oral language latent variable composed of vocabulary and retell was related to comprehension monitoring in fifth graders (Connor et al., 2014), and indicates that meaning construction and integration processes in oral language (Kim, 2016, 2017; Kim & Phillips, 2014) predict comprehension monitoring in reading contexts (see also van der Schoot et al., 2012).

When online comprehension monitoring was examined simultaneously with the two well-known, powerful predictors of reading comprehension—word reading and listening comprehension—it was not uniquely related to reading comprehension. In line with previous studies using latent variable approaches (e.g., Adolf et al., 2006; Kim, 2015, 2017; Silverman, Speece, Harring, & Ritchey, 2013), word reading and listening comprehension explained a vast majority (i.e., 96%) of variance in reading comprehension in the present study. Recent findings suggest that the strong explanatory power of word reading and listening comprehension can be attributed to the fact that word reading and listening comprehension encompass a multitude of component skills of reading comprehension, such as oral language (e.g., vocabulary), low-level cognition (e.g., working memory), and higher order cognition (e.g., inference, monitoring; Kim, 2015, 2017). The present finding of no direct relation of online comprehension monitoring to reading comprehension indicates that that the relation of comprehension monitoring to reading comprehension is indirect via word reading and listening comprehension (Kim, 2015, 2017), which adds to growing evidence by measuring online comprehension monitoring using local rereading time and lookbacks in a normal reading context, whereas previous work examined comprehension monitoring using tasks that demanded a deliberate effort to find anomalies in text (e.g., Cain et al., 2004; Kim, 2015, 2017; Kim & Phillips, 2014; Oakhill & Cain, 2012). To our knowledge, this is the first study that investigated the relation of online comprehension monitoring to reading comprehension after accounting for word reading and listening comprehension.

It will be important for future research to determine whether comprehension monitoring as measured in previous work (i.e., deliberate strategies) and online comprehension monitoring as measured in the present study are expressions of the same monitoring process, or whether they represent different control mechanisms that good readers should have at their disposal (see Kim & Phillips, 2014, for a discussion of the strategy vs. skill continuum of comprehension monitoring). Although the assumption is that the strategy can be trained to evolve into a skill (Afflerbach, Pearson, & Paris, 2008), our data suggest that detecting inconsistencies in written text is already found at the beginning of second grade, as evidenced by the longer rereading duration on target words and the sentence containing target words. One assumption that should be examined in future research is that with growing reading ability, readers will look back at critical preceding text regions (e.g., sentences 1–3 in this study) more often. For more skilled readers, these lookbacks should focus on disambiguating regions and ultimately result in better comprehension. A study with older children at a more advanced reading level would illuminate this question. Furthermore, this process of looking back at the disambiguating regions could certainly be subject to training by intervention.

Although the focus of the present study was comprehension monitoring in the context of reading, a body of literature has shown that comprehension monitoring emerges from the meaning construction process in oral language contexts (Baker, 1984; Kim, 2015; Kim & Phillips, 2014; Markman, 1977; Revelle et al., 1985; Skarakis-Doyle, 2002) and can be effectively taught in oral language contexts even for prekindergartners (Kim & Phillips, 2016). Therefore, explicit and systematic efforts to develop children's comprehension monitoring, whether in written text or oral text contexts, would be important in instruction. In particular, given the essential role of oral language in reading (Hulme, Nash, Gooch, Lervag, & Snowling, 2015; Kim, 2017) and the present finding of a relation between listening comprehension and comprehension monitoring, explicit early instruction on comprehension monitoring in oral language contexts, as well as reading contexts, appears to be a reasonable recommendation. This could promote development of reading comprehension even in primary grades, where decoding instruction takes priority (e.g., Pearson & Duke, 2002).

Reading is a complex phenomenon, requiring coordination of multiple processes and demands. In the present study, we focused on one of the processes—comprehension monitoring—and found that even beginning readers are sensitive to semantic inconsistency in written texts. However, online comprehension monitoring (indicated by greater time spent rereading inconsistent words and texts) was not associated with reading comprehension once word reading and listening comprehension were accounted for. Nonetheless, the present findings have shown the importance of studying moment-to-moment information processing during reading for a better understanding of this complex process.

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Appendix A

Table A1 Examples of Inconsistent and Consistent Stories

Inconsistent stories	There was a rabbit named Fluffy.	Shelly is a cheerful little girl.
	Fluffy's food was always carrots.	She likes to wear only blue clothes.
	He often hopped around in a garden.	In her closet there are many dolls and toys.
	Fluffy ate *cabbage* for his meals.	Today Shelly picked a *yellow* shirt and pants.
Consistent stories	George is a very happy farmer.	Seahorses live in oceans and seas.
	On his farm, George grows only pumpkins.	They are very slow swimmers.
	His farm has a large green field.	Usually they stay in shallow waters.
	George loves growing pumpkins on his farm.	Seahorses move slowly through the water.

Note. Italics indicate embedded target inconsistent word, shown for demonstration purposes here. Italics were not used during data collection.

Appendix B

Distribution of Rereading Time for Target Words Before (Left) and After (Right) Log Transformation