An Investigation of the Role of Sequencing in Children's Reading Comprehension

Article *in* Reading Research Quarterly · April 2017

DOI: 10.1002/rrq.186

3 authors:

Bethanie Gouldthorp
Murdoch University

Lia Katsipis
Murdoch University

Cara Mueller
Murdoch University

INTERNATIONAL LITERACY ASSOCIATION READING RESEARCH QUARTERLY

An Investigation of the Role of Sequencing in Children's Reading Comprehension

Bethanie Gouldthorp
Lia Katsipis
Cara Mueller

Murdoch University, Perth, Western Australia

ABSTRACT

To date, little is known about the high-level language skills and cognitive processes underlying reading comprehension in children. The present study aimed to investigate whether children with high, compared with low, reading comprehension differ in their sequencing skill, which was defined as the ability to identify and recall the temporal order of events in narratives. A novel age-appropriate reading and recall measure was developed to assess sequencing in typically developing primary school students. Sixty-four students between the ages of 8 and 11 years read short narratives containing either a forward or backward temporal shift and then placed a set of cards depicting the scenario in either picture or text format in the correct chronological order that the events occurred. Participants also completed measures of verbal and visuospatial working memory to investigate potential relations between working memory and sequencing ability. High comprehenders were found to produce more accurate sequences than low comprehenders in all conditions of the sequencing task, suggesting that sequencing ability may be important for facilitating comprehension. Additionally, participants produced more accurate sequences in the forward condition than the backward condition, indicating that sequencing is facilitated by chronological presentation of events in text. Measures of working memory were unrelated to sequencing ability or comprehension. The results of this study provide preliminary evidence that sequencing is an important skill for children's comprehension of narrative texts and have implications for reading education and intervention programs.

Evidence suggests that approximately 10% of school-age children demonstrate age-appropriate word-decoding skills yet have difficulty understanding the meaning of what they read (Cain & Oakhill, 2007; Nation, Clarke, Marshall, & Durand, 2004). Although accurate and efficient word decoding is necessary to decipher the words on a page, an additional set of (high-level) skills, reliant on different cognitive and language resources, are required to extract meaning from the text (Oakhill, Cain, & Bryant, 2003). Although-word decoding skills have been extensively researched, the high-level skills underlying children's comprehension remain less well explored. It is likely that these high-level language skills facilitate the comprehension of texts by enabling readers to construct a complete and coherent mental representation of the meaning of a text. Thus, this article describes a preliminary investigation into the high-level skills and cognitive processes underlying children's comprehension, focusing on the mechanisms necessary to construct complete and coherent mental representations of texts. First, we outline the relevant theoretical

Reading Research Quarterly, 0(0)
pp. 1–16 | doi:10.1002/rrq.186

literature that describes these processes, and then we consider this in the context of individual differences in reading comprehension skill.

Situation Models

Central to the understanding of comprehension is the well-established theory that readers construct mental representations of textual information, termed *mental models* or *situation models* (Johnson-Laird, 1983; van Dijk & Kintsch, 1983). Situation models are commonly defined as mental representations of the events, characters, objects, places, and actions described in the text and the relations among them (Tapiero, 2007). They are considered higher level representations because they build on two lower level representations: the surface-level representation, which reflects the exact wording and grammar of the text; and the textbase-level representation, which reflects the meaning of the words, sentences, and grammar contained in the text (van Dijk & Kintsch, 1983). These lower level representations contain information about the text itself and generally fade quickly from memory, whereas the situation model is a more enduring, embodied representation of the state of affairs described by the text (Graesser, Millis, & Zwaan, 1997). Situation models go beyond the words on the page; they are representations of the meaning of the text, rather than the text itself, and are therefore essential for complete comprehension. Evidence suggests that both situation models and mental representations of real-life events are structured in chronological order (Radvansky, Copeland, & Zwaan, 2005). This may be because, as narratives often depict events similar to those experienced in real life, organizing events in the order in which they are perceived in real life may assist readers in making causal connections between events in the past and the present.

Support for the chronological structure of situation models has been provided by studies investigating the recall of narratives that varied the order of event presentation (Claus & Kelter, 2006; Kelter, Kaup, & Claus, 2004). Building on evidence that events become less accessible as more time passes in the described world (Kelter et al., 2004), Kelter and Claus (2005) demonstrated that the first event in a chronological sequence is less accessible than other events, irrespective of the order of presentation in the text. Thus, situation models appear to be chronologically organized, even when the events themselves are not presented in chronological order.

Consistent with the theory that readers construct situation models that reflect real-life experiences of events described in text is the iconicity assumption, which purports that readers expect the order of events in narratives to mirror the order that they are experienced in real life; that is, they should be chronological and continuous (Zwaan, 1996). Indeed, reading speeds slow when readers encounter a shift in time, either backward to past events or forward to a point in the future (Rinck & Weber, 2003; Speer & Zacks, 2005; Zwaan, 1996). Similarly, comprehension is facilitated when events are presented in chronological order in comparison with reverse or other orders for both adults (Ohtsuka & Brewer, 1992) and children 8–12 years old (Kucer, 2010; Pyykkonen & Jarvikivi, 2012). Thus, the order in which events are presented in a text influences comprehension.

However, causal network theory proposes that memory for events is best described as a network of causally related events rather than a linear chain (Tapiero, 2007). Indeed, it has been found that during narrative reading, concepts with more causal connections to other concepts are accessed and recalled more frequently (Trabasso, Secco, & van den Broek, 1984; Trabasso & van den Broek, 1985). Similarly, studies conducted with children have shown that recall of narrative events by young children is much greater when a narrative has more causal connections (van den Broek, Pugzles-Lorch, & Thurlow, 1996), and 4- and 6-year-olds' correct recall of aural or televised narratives, as well as answers to comprehension questions, has been found to be related to their sensitivity to the causal structure of the narratives (Lynch et al., 2008). Thus, some authors have argued that memory for temporal information is weak (W.J. Friedman, 1993) and that events may in fact be organized in memory according to their causal structure (Tapiero, 2007). Brownstein and Read (2007) investigated this and found that adult participants' recall of a television show followed the causal sequence of events more closely than the temporal sequence. Similar monitoring of event sequences has been found to occur regardless of modality (i.e., reading a narrative vs. watching the events in a film; Zacks, Speer, & Reynolds, 2009; for a review, see Kurby & Zacks, 2008). Thus, it appears that although these processes are not modality specific, they may be important for reading and language comprehension.

However, because cause always precedes effect, it is difficult to determine which dimension of events (i.e., causal or temporal) may be more important for the organization of situation models. Moreover, cause-and-effect relations are less likely to be identified when presented out of temporal order (Briner, Virtue, & Kurby, 2012; Fenker, Waldmann, & Holyoak, 2005), suggesting that understanding of temporal order is important for causal links to be encoded in memory.

Individual Differences in Comprehension

Despite evidence that readers construct temporally organized situation models, there is some evidence for individual differences in situation model construction. For example, working memory capacity is likely to influence comprehension. Theoretically, working memory determines an individual's capacity to hold incoming textual information, previously read text, and knowledge from long-term memory and integrate these sources of information to construct a coherent situation model (Graesser, Singer, & Trabasso, 1994). More specifically, working memory is conceptualized here as involving the active manipulation, processing, and temporary storage of information, after which it is either encoded into long-term memory or forgotten (for a review, see Baddeley, 2012). In addition to two components used for processing and integrating information regardless of the modality of the information—the central executive and the episodic buffer—two independent subsystems are proposed to exist for verbal and visuospatial information: the phonological loop and the visuospatial sketchpad, respectively.

Verbal working memory capacity has been consistently related to reading comprehension in adults (Carretti, Borella, Cornoldi, & De Beni, 2009) and children 6–11 years old (Oakhill, Yuill, & Garnham, 2011), and 7–11-year-old high and low comprehenders have been found to differ in their working memory capacity (Oakhill & Cain, 2012). The ability to manipulate information held in memory seems to be of particular importance for reading comprehension ability, as measures of short-term memory that require storage (but not manipulation) of information are unrelated to reading comprehension in children ages 8–14 (Carretti et al., 2009). In general, the vast literature on working memory suggests that it contributes to comprehension primarily through its effects on integration of information and coherence monitoring. Consistent with this, working memory tasks that require both storage and additional processing of information have more often been found to correlate with children's reading comprehension than tasks that assess passive storage capacity (Daneman & Merikle, 1996). However, Cain, Oakhill, and Bryant (2004) found that after controlling for word-reading ability and verbal IQ, the relations between reading comprehension and both inference making and comprehension monitoring were not entirely mediated by verbal working memory and that each component provided its own unique variance.

Thus, additional resources must play a role in these higher level language-processing skills. For example, as evidence suggests that situation models contain perceptual and spatial information, visuospatial working memory or visual imagery may also play a role. However, few studies have investigated the role of visuospatial working memory specifically in relation to component skills of reading (e.g., coherence monitoring), and findings regarding its contribution to overall reading comprehension have been mixed. For example, measures of verbal working memory (e.g., reading or digit span tasks), not visuospatial working memory (e.g., pattern or matrix span tasks), have been consistently related to reading comprehension in children (Cain et al., 2004; Carretti et al., 2009). Both verbal and visuospatial working memory components have been shown to predict overall reading comprehension level. Yet, other work (e.g., N.P. Friedman & Miyake, 2000) has found evidence that separate working memory subsystems, including visuospatial representations, are implicated in the construction and monitoring of different situation model dimensions.

In addition to working memory capacity, situation model construction may be constrained by individual differences in high-level language skills. To date, studies have identified three main differences between good and poor comprehenders with equivalent word-decoding skills: comprehension monitoring, inference generation, and knowledge of text structure (Oakhill & Cain, 2012). This research indicated that 7–11-year-old poor comprehenders are less likely to identify inconsistencies in the text, generate fewer inferences, and subsequently construct less complete mental representations of the text than peers who are good comprehenders (Cain, Oakhill, Barnes, & Bryant, 2001; Oakhill & Cain, 2012).

Additionally, at ages 7–9, poor comprehenders have been found to demonstrate less knowledge of text structure than peers who are good comprehenders (Oakhill et al., 2003). Reviews of the literature on studies conducted with children suggest that knowledge of text structure (e.g., that a story has a beginning, middle, and end) may facilitate comprehension by providing a framework from which skilled comprehenders can make predictions and identify and integrate important information (Cain, 2009). This is one aspect of sequencing ability, which is also defined as the ability to understand and recall the order of events (Eilers & Pinkley, 2006). As described earlier, this ability is also influenced by the chronological presentation of information, as well as knowledge of causal relationships.

In relation to this, Blything, Davies, and Cain (2015) found that 3–7-year-old children displayed more difficulty with sequencing temporal information when this information was presented in reverse rather than chronologically (e.g., "Before he ate the burger, he poured the ketchup" vs. "He poured the ketchup, before he ate the burger"; p. 1926), despite having sufficient vocabulary knowledge of temporal cues such as *before*.

Thus, it appears that even by this young age, children are sensitive to the temporal information presented in narratives. In addition, this aspect of sequencing skill was found to be dependent on processes such as the ability to retain information in working memory (Blything et al., 2015). Beyond this, however, few studies have explored how children process temporal information to sequence story events. Furthermore, whether this skill contributes specifically to reading comprehension remains unexplored.

Aims and Hypotheses

We propose that understanding and recall of the temporal order of events may facilitate situation model construction, and thus reading comprehension ability, in children. This is based on the rationale that understanding the temporal order of events (hereafter referred to as sequencing) may assist readers in identifying the relations between elements and events in texts and thereby facilitate the construction of a complete and coherent situation model. Consequently, individual differences in sequencing ability may differentiate those with high comprehension from those with low comprehension. Accordingly, the aim of this study is to investigate whether children who have high levels of comprehension differ in their sequencing ability compared with those who have lower levels of comprehension.

To investigate potential differences in sequencing ability in typically developing primary school students, a novel reading and recall measure was developed. Participants read short narratives that contained either a forward or backward temporal shift, and then placed a set of cards depicting the scenario in the correct chronological order (i.e., not necessarily the order presented in the story). The cards represented narrated events in either text or picture format to allow for individual differences in verbal or visual processing preferences. Participants were classified as either high or low comprehenders using a standardized reading measure. To investigate whether differences in sequencing ability were related to working memory capacity, measures of verbal and visuospatial working memory were included.

It was hypothesized that high comprehenders would more accurately identify and recall the temporal sequence of events across all conditions (total sequencing score) than low comprehenders. Additionally, as comprehension may be more difficult for nonchronological than chronological narratives, it was hypothesized that the backward condition of the sequencing task would be more difficult than the forward condition for all participants and that high comprehenders would perform significantly better than low comprehenders in both conditions. It was further hypothesized that verbal working memory capacity would be correlated with both comprehension and sequencing ability but would not account for differences in sequencing ability between high and low comprehenders.

Method

Participants

Sixty-nine primary school students (35 males, 34 females) were recruited from six primary schools across a metropolitan area via mailings to parents following teacher approval and allowing voluntary opt-in. Participants were in grades 3–5, with ages ranging between 8.25 to 10.83 years (mean [*M*] = 9.61 years, standard deviation [*SD*] = 0.60 years). These schools are in a wide range of socioeconomic areas, according to the Australian Index of Community Socio-Educational Advantage ratings; at the time of the present study, the schools' index scores ranged from 885 to 1153 (the median score is 1000, and the total range of ratings across the metropolitan area is approximately 801–1211), and an effort was made to recruit comparable numbers of students from within each stratum of this range to minimize sampling bias.

All participants had normal or corrected-normal vision, were free from cognitive impairment, and spoke English as their first language. To reduce the possibility of poor word-decoding skills limiting performance on reading tasks, participants were initially screened using the third edition of the Neale Analysis of Reading Ability (NARA–III; Neale, 1999) reading accuracy subscale, and those with low scores (below 34 for students in year 4 and below 39 for students in year 5) were excluded. Five participants were excluded using this criterion.

Design

This study employed a 2 × 2 × 2 mixed-measures design to investigate the between-groups independent variable of reading comprehension (high or low), the within-groups independent variables of direction (forward or backward temporal shift), and stimulus medium (text or picture). The dependent variables were sequencing ability (as indicated by accuracy in the novel sequencing task) and comprehension ability (as reflected by NARA–III comprehension scores). Additional correlational analyses were conducted between the independent variables of working memory (verbal and visuospatial), sequencing, comprehension, and reading accuracy.

Materials

Comprehension and Reading Accuracy

To assess comprehension and reading accuracy, all participants completed Form 1 of the NARA–III. The NARA–III was developed for use with students ages 5–12 years and has been standardized for the Australian population (Neale, 1999). It has demonstrated high reliability and validity; for example, internal consistency reliability (Kuder–Richardson formula 21) was reported at .85 for reading comprehension for students in year 4 and .96 for students in year 5 (Neale, 1999). High test–retest validity was also reported: .83 for accuracy and .78 for comprehension. Reading accuracy scores were determined by collating the number of reading errors across passages and subtracting from 100, giving a maximum possible score of 100. The comprehension score was the sum of the correctly answered comprehension questions, with a maximum possible score of 44.

Sequencing Task

No measure of sequencing ability (measuring understanding and recall of event order rather than knowledge of text structure) exists for typically developing children of this age, thus a novel measure was developed. Two narratives were constructed for each level of the direction condition (forward and backward temporal shift), plus an additional backward shift narrative for use as a practice task (for examples of each narrative type, see Appendix A, which is available as supporting information for the online version of this article). The backward condition was included to ensure that participants were attending to the order in which events occurred in the narrated world, rather than recalling the order of presentation from the text.

Narratives contained temporal shifts of one week or one year (forward and backward conditions contained one of each), indicated by phrases such as “the following Saturday” and “last week” (see Appendix A). Existing literature suggests that these cue words act as temporal markers, and, thus, are important for the inclusion of temporal order within the situation model (Zwaan, 1996; Zwaan & Radvansky, 1998). Specifically, although cue words make these temporal relationships explicit, these words become meaningful because they provide temporal information about the events in the story and allow these events to be organized within a situation model based around a temporal framework (Zwaan & Radvansky, 1998). For example, sequencing cues such as time adverbs have been theorized as activating situational nodes, allowing information to be foregrounded; for example, research has suggested that phrases such as “a moment later” prompt readers to maintain activation of a previously established node, whereas temporal discontinuities such as “a day later” act as a cue for readers to decrease activation of the previously constructed node and construct a new time interval (Zwaan, 1996). Consequently, research has demonstrated that temporal shifts of the magnitude used in the current study are interpreted as event boundaries and elicit the construction of a new situation model (Rinck, Hähnel, & Becker, 2001; Speer & Zacks, 2005).

Theoretically, the task requires readers to construct multiple situation models and retrieve information from short-term memory (the active situation model) and long-term memory (the previous situation model). This is a novel approach, as previous tasks investigating temporal shifts have employed narratives likely to elicit the construction and updating of a single situation model (Claus & Kelter, 2006; Kelter & Claus, 2005; Ohtsuka & Brewer, 1992). Thus, this measure taps participants’ ability to integrate and organize sequences of events across multiple situation models rather than within a single situation model. Furthermore, to ensure that students had sufficient knowledge of temporal cue words, students who did not demonstrate age-appropriate word-reading ability were not included in the current study. In addition, recent research has suggested that by age 7, children perform at high levels of accuracy on tasks that require an understanding of temporal cue words (e.g., Blything et al., 2015). Thus, in this population, differences in the ability to apply meaning to sequence cue words in the sequencing task can be viewed as a reflection of differences in the ability to activate and subsequently provide temporal information about the events in a story, rather than differences in the ability to process textbase information such as the cue words themselves.

To avoid the effects of story familiarity on situation model construction and task performance, original narratives were developed. Care was taken to ensure that text comprehension was required to successfully complete the task, thus narratives contained novel event sequences with arbitrarily ordered events. This is because schema-based sequences, for which the reader has prior knowledge of the order in which events occur (e.g., taking a bath), may be constructed from the reader’s background knowledge (Miller, Stine-Morrow, Kirkorian, & Conroy, 2004) without reading the text. Similarly, sequences of events with an obvious cause-and-effect relationship (e.g., it started to rain, so she put up her umbrella) were avoided to ensure that text comprehension was required to complete the task.

To increase task engagement, each narrative was presented in storybook format on A5-sized paper in 20-point font size centered on the page, with one main event per page (six pages in total). Story lengths ranged from 204 to 241 words in total (M = 222.4 words), with 34–40 words per page (M = 36.9 words). Each story was similar in structure, written in the third person from the perspective of one main protagonist. All narratives began in the present (pages 1–3), with a temporal shift occurring on page 4 and subsequent events set in either the future or past (pages 5 and 6). Thus, for each narrative, three events take place in the present, and three events take place in the past or future.

Textual and pictorial target stimuli were constructed to accompany the narratives: six cards describing the main events of the story in text and six cards depicting main events in cartoon format. Samples of stimuli for each condition are included in Appendix A. The text condition was included to determine participants' sequencing ability; the picture condition was included to account for individual differences in verbal and visuospatial processing preferences. All stimuli were centered on white 10- × 8-cm laminated cards. Textual information was presented in a black, 16-point font and summarized each event in the story (e.g., "The cake catches fire in the oven"). The number of words per card ranged from four to 15 (M = 8.2 words).

Pictorial stimuli were 7 × 6.5 cm. Each image was designed to clearly depict the same information described by the corresponding text stimuli for each event. To ensure that pictorial stimuli conveyed the relevant information, a pilot group (N = 15; M age = 9.2 years) was shown the images for each narrative and asked to describe what each image represented. Images were altered according to participant feedback until consistency with the text passages occurred (100% agreement).

Scores were calculated by comparing the sequence produced with the correct sequence; 1 point was awarded for each position from its absolute correct position a card was placed (e.g., if card 3 was placed in position 1, 2 points were awarded). This gave a maximum possible score of 18 for each condition. Scores were summed to calculate total forward, backward, text- and picture-sequencing scores (maximum of 36 each), and total sequencing score (maximum of 72). Scores were then reverse-coded so higher scores reflected greater sequencing ability.

Working Memory

An image-scanning task (Kosslyn, Cave, Provost, & von Gierke, 1988; Kosslyn, Margolis, Barrett, Goldknopf, & Daly, 1990) requiring participants to maintain an image over time and manipulate this information by integrating different parts of the maintained image was used as a measure of visuospatial working memory. Response times and error rates were recorded, and the percentage of correct items was used as a measure of visuospatial working memory capacity, giving a maximum possible score of 100.

A computerized backward digit span task was included as a measure of verbal working memory span. A numeric task was selected in preference of reading span working memory tasks to eliminate the possibility of individuals' word-based skills limiting their performance (Cain et al., 2004), as word or sentence span tasks may provide better readers with an additional advantage that is unrelated to working memory (see Nation et al., 2004). Further, digits are readily amenable to verbal coding but would likely be harder than words to encode visually, which are more susceptible to dual coding. Therefore, this increased the likelihood that the verbal working memory measure would be distinct from the visual working memory measure. Although specific reliability and validity data are not available for the software used, backward digit span tasks are considered appropriate for assessing verbal working memory in this age group (Conway et al., 2005). For each measure, the longest sequence for which two correct responses were recorded was taken as the score for the task.

Apparatus

All memory measures were presented on a Toshiba Satellite C660 laptop computer with a 34.5- × 19.5-cm screen with 1280 × 720 pixel resolution, 32-bit color, and an 85-Hz refresher rate, running on a 2.10-GHz processor with a Windows 7 operating system and 2 GB of RAM. The digit span task was run using version 0.13 software available from The Psychology Experiment Building Language (http://pebl.sourceforge.net/); the visuospatial memory task was run using DirectRT version 2010 software. A nine-button DirectIN High Speed Button-Box/EmpiriSoft version 2012 response box was connected to the computer via a USB. The far left button corresponded with a yes response and the far right button with a no response, and the two buttons were labeled to prevent confusion.

Procedure

All testing sessions took place on school grounds in a quiet room separate from the classroom. Testing was conducted over two sessions (on different days, generally a minimum of one week apart) to reduce fatigue and maintain engagement throughout the tasks. Rest breaks of approximately five minutes were encouraged between each measure. Participants completed the NARA–III first to ensure that they possessed adequate word-reading skills to complete the tasks.

The NARA–III was administered in accordance with the guidelines provided by the author (Neale, 1999). Participants were verbally instructed to read aloud passages of graded difficulty and informed that an audio recording would be made (using a small, portable digital recording device to allow for cross-marking with a second experimenter to ensure consistency), but advised that it was most important to attend to the content of each passage to answer questions about the text. Any reading errors (e.g., omissions, mispronunciations) were recorded and the correct word supplied during reading. Immediately following completion of reading, participants were asked predetermined questions to assess comprehension. The task took approximately 20 minutes to complete.

Following the NARA–III, participants were provided with verbal instructions for the sequencing task (see Appendix B, which is available as supporting information for the online version of this article). These instructions included a description of what flashbacks are and a discussion between the experimenter and participant about temporal sequence cues (e.g., "last week" vs. "last year") to confirm that participants understood what these temporal cue words mean. Participants were then asked to read the practice story. After reading, the corresponding picture stimuli for the practice story were placed on the table before the participant in the order of presentation in the story (with the first card on the left and the last card on the right, in a straight line). Participants were advised to clarify with the experimenter if they were unsure what a picture represented, in which case an explanation matching the corresponding text stimuli was provided. Participants were asked to indicate (by pointing) which cards related to the flashback sequence (and corrected if necessary) and to place the cards in temporal order, from left to right, with assistance if unsure. Next, participants were given the corresponding text cards and asked to demonstrate the sequence of cards "in order of time." For both the picture and text versions, further instruction and explanation were provided if the participant was unable to complete the task correctly or showed difficulty in understanding either the temporal cues or the task requirements. Once participants felt confident with the task instructions, they were given the first storybook, followed by the first set of stimuli (either text or pictorial).

Task order was determined by stimulus sets constructed prior to test administration, so each participant completed one trial for each of the four sequencing conditions (forward text, forward picture, backward text, and backward picture). Task order was counterbalanced across participants to reduce order effects and to ensure that an equal number of participants received the text and pictorial stimuli for each narrative. This generated a total of 96 stimulus sets.

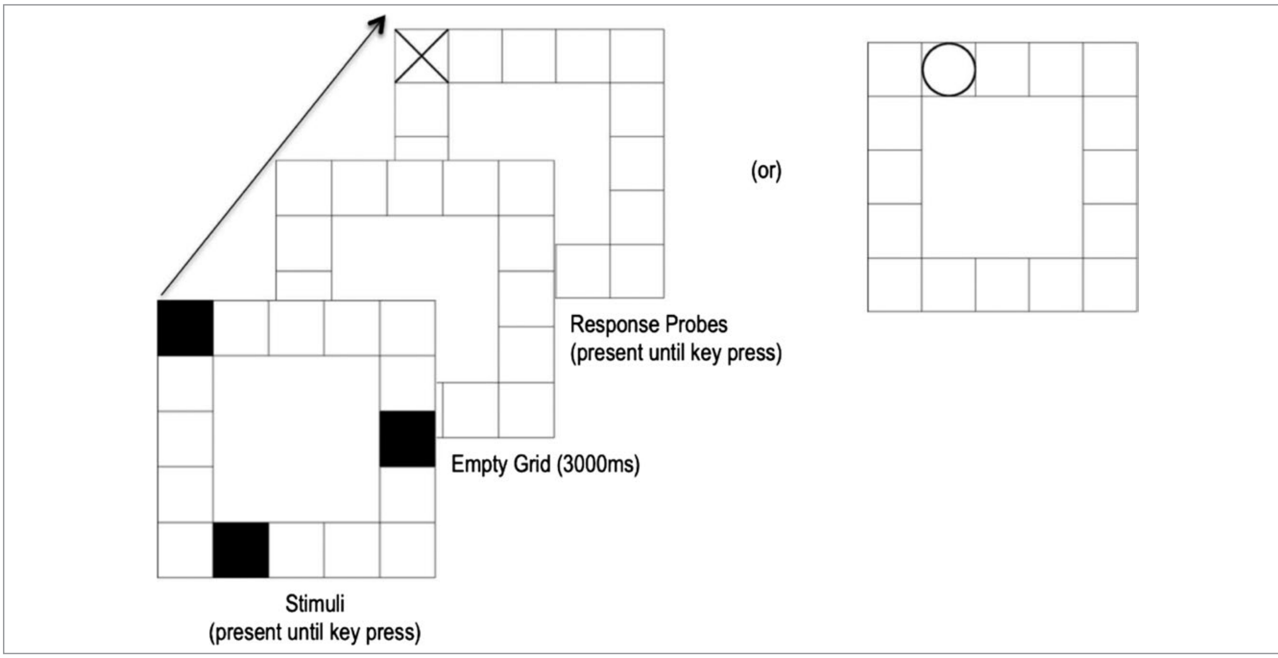
Participants worked independently and verbally informed the test administrator when they were ready to commence the next section of the task. Scores for each trial were determined by comparing the sequence produced with the correct sequence and then recorded by the experimenter. Each participant completed either the text or picture trial for each of the four stories, so each participant completed one trial for each of the four conditions: forward shift text, forward shift pictorial, backward shift text, and backward shift pictorial. The task took an average of approximately 20 minutes to complete.

At testing session 2, participants were seated in front of the laptop, familiarized with the response box, and instructed to keep their left and right hands over the corresponding, assigned Yes and No response buttons. Patterns imposed on a grid (174 × 74 mm with a visual angle of 7.50° × 9.00°) were presented in the center of the screen, in black on a white background. Sample stimuli are presented in Figure 1. A large grid was used, and participants were positioned approximately 30 cm from the screen to prevent viewing of the whole grid at once, forcing them to scan across the image.

In each pattern, three cells were filled, with no more than two adjacent (horizontally, vertically, or diagonally) cells filled. Participants were presented patterns imposed on a grid and indicated when they had memorized the pattern by pressing any key. The pattern disappeared, leaving an empty grid for 200 ms before a probe appeared in one of the cells. In control condition trials (A), an X probe appeared, signaling that the participant should indicate whether the probe fell in a cell previously filled by pressing the Yes or No button on the response box. For test condition trials (B), an O probe signaled that the participant should indicate whether the probe fell in a cell opposite to a previously filled cell (i.e., the cell diagonally opposite if the probe fell in a corner cell or in the cell directly opposite the previously filled cell, across the gap in the center). Five practice trials were first completed (an additional five trials were offered but skipped if not required), and any key was pressed to commence the task. Trials were presented in a randomized order generated by the computer. For each condition, 14 trials were presented: seven (50%) requiring a yes response and seven (50%) requiring a no response, for a total of 28 trials.

Upon completion of this task, the administrator launched the backward digit span task and entered the participant code into the computer. Participants were told to ignore the on-screen instructions, which are designed for adults, and instead age-appropriate verbal instructions were provided. Participants were presented with single-digit number sequences randomly generated by the computer from the digits 0–9, with no number repeated in a single sequence. Before each trial, a message was displayed on the screen indicating the length (number of digits) of the next sequence. Numbers were displayed in black, 22-point text centered on a white screen for 1,000 ms before disappearing; 1,000 ms later, the next digit in the sequence was displayed.

FIGURE 1
Sample Stimuli for the Control and Test Conditions of the Image-Scanning Task



Following presentation of the last digit in the sequence, a prompt appeared on-screen, and participants entered the digits in the opposite order to which they were displayed using the laptop's numerical keypad. Participants were advised to take care when entering answers, as responses could not be altered once entered. The first block contained three trials of three-number sequences. If two or more sequences in each block were recalled correctly, participants advanced to the next block of four-number sequences. The task progressed in this manner until the participant failed two or more trials in a block. The longest sequence length for which two correct responses were recorded was used as the verbal working memory score. The task took approximately five minutes to complete.

Results

Data Screening

Response time and accuracy scores for the test condition of the image-scanning task were screened for outliers before conducting analyses. To detect trials likely to reflect a lapse in concentration, individuals' mean response times were calculated for each condition, and scores more than double the mean time were coded as errors along with incorrect responses. Participants with accuracy scores less than 50% (more than seven errors) were excluded. This resulted in the exclusion of one participant from this task. A further screening process was applied to the raw scores for all tasks using a winsorization process (Barnett & Lewis, 1994), whereby all outliers (greater than (3.0 *SD*s) were replaced with a value corresponding to 3.0 standard deviations above or below the sample mean for that condition. A total of 0.65% of scores was adjusted in this screening process. Chronological age at time of testing was calculated in years, and scores on the sequencing task were reverse-coded so higher scores indicated better performance.

Normality and Descriptive Statistics

Initial visual and statistical investigations revealed that data for all variables except comprehension violated normality assumptions, as evidenced by significant Kolmogorov–Smirnov tests ($p > .05$) and skew and kurtosis z-scores above 2.58. In particular, a strong ceiling effect was observed for all conditions of the sequencing task. The effect of splitting cases by age, year of schooling, comprehension level, and reading accuracy was investigated, and log, reciprocal, square root, and arcsine transformations were attempted but did not result in data satisfying the normality assumption. Thus, nonparametric analyses were conducted. Descriptive statistics are displayed in Table 1.

Sequencing Task Reliability

Preliminary analyses were conducted to investigate the psychometric properties of the sequencing measure. To determine whether the two narratives developed for

TABLE 1
Summary of Median Values, Ranges, and Standard Deviations (*SD*s) of Overall Scores on Assessments and Within Groups of High and Low Comprehenders

Measure	High comprehenders (n = 31) Median (range)	High comprehenders *SD*	Low comprehenders (n = 33) Median (range)	Low comprehenders *SD*	Overall (n = 64) Median (range)	Overall *SD*
Age	9.58 (8.25–10.83)	6.89	9.50 (9.00–10.58)	0.47	9.50 (8.25–10.83)	0.60
Reading accuracy	84 (46–96)	14.08	61 (35–92)	19.28	76 (35–96)	19.01
Comprehension	27 (23–40)	4.10	17 (10–22)	3.56	22 (10–40)	6.79
Total sequencing	64 (7–72)	17.35	47 (22–70)	15.31	54 (7–72)	17.19
Forward text sequencing	72 (54–72)	5.03	70 (54–72)	5.94	72 (54–72)	5.47
Forward picture sequencing	72 (54–72)	5.57	66 (54–72)	6.09	70 (54–72)	6.10
Backward text sequencing	72 (54–72)	5.90	62 (54–72)	6.25	68 (54–72)	6.35
Backward picture sequencing	68 (53–72)	6.22	66 (54–72)	5.64	68 (53–72)	5.99
Forward sequencing	34 (0–36)	9.72	28 (0–36)	10.56	30 (0–36)	10.28
Backward sequencing	32 (0–36)	10.23	20 (2–36)	9.60	24 (0–36)	10.31
Text sequencing	34 (8–36)	8.78	24 (6–36)	9.02	24 (6–36)	9.25
Picture sequencing	31 (0–36)	10.37	22 (4–36)	9.39	27 (0–36)	10.18
Backward digit span	4.00 (3.00–6.82)	0.95	4.00 (2.00–6.00)	0.87	4.00 (2.00–6.82)	0.93
Image scanning	85.71 (50–100)	14.49	85.71 (50–100)[a]	13.05	85.71 (50–100)[b]	13.67

[a]*N* = 32. [b]*N* = 63.

each level of the direction condition (forward and backward) were of equivalent difficulty, independent-samples Mann–Whitney U tests were performed for the text and picture conditions. The results revealed that for the text condition, performance on narratives A (median [*Mdn*] = 18.0, range = 0–18) and B (*Mdn* = 18.0, range = 2–18) in the forward condition was roughly equivalent, as was performance on narratives C (*Mdn* = 14.0, range = 0–18) and D (*Mdn* = 12.5, range = 0–18) in the backward condition. However, significant differences were found in median scores of the picture task between narratives A (*Mdn* = 18.0, range = 1–18) and B (*Mdn* = 12.0, range = 0–18) for the forward condition (U = 344.00, p = .021, r = .29) and narratives C (*Mdn* = 12.5, range = 0–18) and D (*Mdn* = 16.0, range = 0–18) in the backward condition (U = 657.50, p = .048, r = –.25), suggesting some variation in the difficulty of the stories.

However, item-level analyses showed excellent internal consistency within stories (Cronbach's α = .91, which was only minimally affected by deletion of individual items, ranging from .89 to .92). Additionally, the corrected item–total correlations indicated that all items within each of the stories showed excellent discrimination (r = .67–.89) in relation to the story-level scores. Further, acceptable internal consistency across each condition type (i.e., pictures or text, forward or backward) was demonstrated (Cronbach's α = .657), and the corrected item–total correlations for each story type indicated that they each produced modest to good discriminability (r = .32–.57).

Working Memory Analyses

To investigate potential relations between working memory and sequencing, two-tailed bivariate Spearman's rho correlations were conducted to compare each condition of sequencing ability (forward text, forward picture, backward text, and backward picture), total sequencing scores (total, forward, backward, text, and picture), and verbal and visuospatial working memory measures (see Table 2). Due to the large number of correlations, a conservative α level (.01) was used. Using this criterion, no significant relations were found between measures of memory and sequencing. Due to the correlations between working memory and sequencing indicating that there

TABLE 2
Summary of Spearman's Rho Correlation Coefficients Between Variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Accuracy	—												
2. Comprehension	.48*	—											
3. Forward text shift	.02	.17	—										
4. Forward picture shift	.15	.33*	.54*	—									
5. Backward text shift	.25	.43*	.28	.26	—								
6. Backward picture shift	.24	.28	.21	.46*	.41*	—							
7. Total sequencing score	.26	.46*	.58*	.73*	.71*	.73*	—						
8. Forward sequencing score	.14	.32*	.81*	.91*	.28	.41*	.75*	—					
9. Backward sequencing score	.30	.39*	.26	.41*	.82*	.83*	.84*	.40*	—				
10. Text sequencing score	.17	.41*	.66*	.43*	.88*	.40*	.83*	.57*	.74*	—			
11. Picture sequencing score	.24	.35*	.45*	.81*	.41*	.86*	.87*	.74*	.74*	.50*	—		
12. Verbal working memory	.10	.30	.10	−.04	−.16	−.04	−.06	.00	−.11	−.08	−.05	—	
13. Visuospatial working memory	.10	.10	.15	.02	.06	.19	.15	.10	.19	.10	.16	.12	—

*$p < .01$.

were only nonsignificant relations, none of the working memory measures were included as covariates in subsequent analyses. Correlations were also performed to investigate whether there was a relation between working memory measures (verbal and visuospatial), reading accuracy, and comprehension (see Table 2). No significant correlations were found.

Sequencing and Comprehension

These correlations also served as an initial investigation of the relation between sequencing ability, reading accuracy, and comprehension. Comprehension was significantly correlated with reading accuracy and the total sequencing score. Significant correlations were also found between comprehension and total scores on the forward, backward, text, and picture conditions separately. Thus, it appears that sequencing ability is related to comprehension ability in this sample of primary school students. The results are displayed in Table 2.

Differences in Sequencing Ability Between Comprehension Groups

To investigate the hypothesis that high comprehenders have better sequencing ability than low comprehenders, comprehension scores were transformed via a median split and then analyzed using a Mann–Whitney U test; the median score was 22, and scores for the low-comprehension group ranged from 10 to 22, whereas scores for the high-comprehension group ranged from 23 to 40. As comprehension data met normality assumptions, an independent-samples *t*-test was used to confirm a significant difference between high and low comprehenders, $t(62) = 11.61, p < .001, r = .83$; this demonstrated that comprehension scores of high comprehenders ($M = 28$, $SD = 4.10$) were significantly higher than those of low comprehenders ($M = 16.72, SD = 3.56$). For all subsequent analyses, a Holm–Bonferroni adjustment was applied to the α level (.05) to reduce the risk of Type I error. An independent-samples Mann–Whitney U test revealed a significant difference between the total sequencing scores of high and low comprehenders ($U = 279.50$, $p = .002$, $r = −.39$), with high comprehenders performing better overall on the sequencing measure than low comprehenders (see Table 1).

A related-samples Wilcoxon signed-rank test was conducted to investigate the hypothesis that performance would be higher for the forward-sequencing condition than for the backward-sequencing condition. A main effect was found for the direction of the temporal shift ($T = 452.50$, $p = .020$, $r = −.09$), demonstrating that participant performance was better overall for narratives containing a forward temporal shift than narratives containing a backward temporal shift. A Mann–Whitney U test was then conducted, demonstrating that the between-groups main effect of comprehension was maintained for both the forward condition ($U = 362.50, p = .041, r = −.26$) and the backward condition ($U = 309.50, p = .006, r = −.34$).

To further investigate the interaction between comprehension and the direction of temporal shift, the effect of the temporal shift was examined separately for the two comprehension groups using a related-samples Wilcoxon signed-rank analysis. This interaction was not significant, suggesting that although both the high comprehenders and the low comprehenders performed better in the forward-sequencing task than in the backward-sequencing task, this difference in performance between conditions was not significant (T = 195.50, p = .193, r = −.17, and T = 302.50, p = .066, r = −.22, respectively).

To investigate differences in performance on the text- and picture-sequencing tasks, related-samples Wilcoxon signed-rank tests were performed on the overall sample and within each comprehension group. No significant main effect or interaction was found (highest T = 650.50 for the main effect of medium in the overall sample). To investigate the interaction between medium and comprehension, an independent-samples Mann–Whitney U test was performed to compare performance between high- and low-comprehension groups on the text- and picture-sequencing tasks. Results indicated that high comprehenders performed significantly better than low comprehenders on both the text-sequencing (U = 295.00, p = .003, r = −.37) and picture-sequencing tasks (U = 350.50, p = .030, r = −.27).

A 2 (direction: forward, backward) × 2 (medium: text, picture) related-samples Friedman two-way analysis of variance demonstrated a significant interaction between direction and medium, $\chi^2_F(3) = 10.87$, p = .012. Subsequent related-samples Wilcoxon signed-rank tests demonstrated that the forward text-sequencing condition was significantly easier overall than the forward picture-sequencing (T = 209.50, p = .031, r = −.23) and backward picture-sequencing conditions (T = 318.00, p = .009, r = −.23). No other interactions were significant. The same analyses were then carried out separately for the high- and low-comprehension groups. A significant interaction between direction and medium was found only for the low-comprehension group, $\chi^2_F(3) = 11.93$, p = .008; subsequent Wilcoxon signed-rank tests revealed that the forward text-sequencing condition was significantly easier than the backward text-sequencing condition (T = 107.50, p = .010, r = −.32), but no other significant interactions were found.

Discussion

The aim of this study was to investigate whether children with a higher level of reading comprehension possess better sequencing skills than children with lower levels of comprehension ability. Based on the rationale that understanding and recall of the temporal order of events in narratives facilitate the construction of a complete and accurate situation model and are therefore important for successful comprehension, it was hypothesized that individuals with higher comprehension scores would demonstrate more accurate recall of event sequences than those with lower comprehension scores. This hypothesis was supported, as high comprehenders performed significantly better than low comprehenders on the overall sequencing task. Moreover, as predicted, high comprehenders produced more accurate sequences than low comprehenders did in the forward and backward conditions and the text- and picture-sequencing tasks. This indicates that high comprehenders were better at identifying the temporal sequence of events and recalling event sequences in general, irrespective of the task medium. Additionally, support was found for the hypothesis that sequencing of events in nonchronological narratives would be more difficult in comparison with chronological narratives, as evidenced by significantly better performance across participants between the forward and backward conditions (although this difference was not evident within the comprehension groups).

In light of strong evidence that verbal working memory capacity is related to comprehension (e.g., Carretti et al., 2009), it was expected that a similar relation would be observed in the present study. However, sequencing was not found to be related to any of the measures of working memory. Rather than demonstrating the absence of a real relation, there are several possible explanations for this result, which are explored in the following subsections.

Differences in Sequencing Ability Between Comprehension Groups

The results of this study provide preliminary evidence that sequencing is an important skill for the comprehension of narrative texts. However, it is important to note that the overall sequencing task is a novel measure, so further evaluation of its psychometric properties is necessary (although preliminary evidence in support of its validity and reliability has been presented). Additionally, although a strong ceiling effect was found for scores on the overall sequencing task, the presence of a significant difference in sequencing ability between high and low comprehenders despite the relative ease of the sequencing measure is encouraging, as presumably a measure of greater difficulty would better distinguish between higher levels of sequencing ability and thus detect a greater difference between groups. For example, task difficulty could be increased by introducing additional conditions of greater difficulty to the sequencing task (i.e., by including texts with additional event boundaries) to reduce the ceiling effect and test this proposition.

The results of this study may also be interpreted from the perspective of causal network theory. From this perspective, causal (rather than temporal) information is important for constructing and recalling event sequences. As the temporal and casual orders of events covary (because cause precedes effect), it is difficult to determine which dimension readers are monitoring. Yet, there is some evidence to suggest that causally related events are more likely to be encoded into memory (Radvansky & Copeland, 2001) and that recall of events more closely follows a network of causal relations than the temporal order (Brownstein & Read, 2007). Importantly, however, cause-and-effect relations are less likely to be identified when presented out of temporal order (Briner et al., 2012; Fenker et al., 2005), suggesting that understanding of temporal order is important for casual links to be encoded in memory.

Thus, it may be argued that although causal links may be more important for the retrieval of information, understanding of temporality facilitates the identification of links between events and characters and inference generation during situation model construction. Additionally, causal links between events in narratives were minimized and in themselves did not provide enough information to successfully complete the tasks. For example, "Fido the dog runs through the kitchen" and "The cake catches fire in the oven" were causally unrelated sequential main events presented in the narrative, thus comprehension of temporal order was necessary to successfully construct the sequence. Therefore, it is reasonable to conclude that the findings of this study demonstrate the use of temporal information, rather than causal links, to sequence events.

Alternatively, the difference in performance on the overall sequencing task between comprehension groups may be interpreted as a differential ability to accurately identify the main events in narratives rather than sequencing per se. Indeed, children who are low comprehenders have been found to identify and recall fewer main events from narratives than those who are high comprehenders (Yuill & Oakhill, 1991). This interpretation may also account for the lack of difference in the scores of low comprehenders between the forward and backward conditions; that is, if the low comprehenders were unable to effectively identify the main events in the narratives, then they would be unable to sequence events. However, the same finding was observed in the high-comprehension group, who displayed an ability to sequence main events, and therefore the lack of difference between the forward and backward conditions cannot be attributed to a difficulty in identifying main events.

Additionally, it has been argued that difficulty in identifying main events is likely due to poorer recognition of causal connections between events and characters, rather than events explicit in the text (Cragg & Nation, 2006). Because all information required to complete the overall sequencing task was explicit in the text, it may therefore be argued that differences in performance are more likely to reflect variations in sequencing ability. Therefore, because observed effect sizes for between-group differences were small, the absence of a difference in performance between forward and backward conditions may best be interpreted as a loss of power to detect effects due to the reduced sample size when examining within-group differences. However, when not split by comprehension level, overall participant performance was significantly greater (i.e., more accurate sequences) on the forward sequences than on the backward ones. This finding is in line with previous evidence that comprehension is poorer for nonchronological narratives than chronological (Kelter & Claus, 2005), including studies conducted with children of a similar age group to those included in the current study (Kucer, 2010; Pyykkonen & Jarvikivi, 2012) and younger (Blything et al., 2015).

Narratives in this study contained a significant time shift that was likely to elicit the construction of a new situation model, and events occurring at each point in time (present and past or future) were presented in chronological order. In contrast, previous studies (Claus & Kelter, 2006; Kelter et al., 2004) presented nonchronological narratives likely to be interpreted as a single event and therefore integrated into a single situation model. In light of evidence suggesting that readers construct temporally organized situation models, the authors of these studies theorized that comprehension is made more difficult by the cognitive demands of reorganizing mental representations to reflect chronological order (Claus & Kelter, 2006; Kelter et al., 2004). However, the task used in this study required participants to reorder multiple situation models to reflect the temporal sequence, rather than reordering events within an individual situation model. Thus, this study extends current knowledge by providing evidence that nonchronological narratives are more difficult to comprehend, even when time shifts do not necessitate the reordering of events within a single situation model, suggesting that difficulties in constructing temporal sequences extends beyond situation model construction.

Sequencing Ability and Memory

Despite a strong rationale for the involvement of working memory processes in the ability to keep active and manipulate narrative events temporally, no relation was found with sequencing ability. Although unpredicted, this finding is nevertheless consistent with some lines of research investigating correlations between working memory and situation model processes such as updating

(Radvansky & Copeland, 2001) and integration (Radvansky & Copeland, 2006). In contrast, working memory has been associated with recall of text-based information (Radvansky & Copeland, 2004); thus, it may be argued that current measures of working memory are not associated with comprehension because they reflect one's ability to retain text-level information (e.g., words, digits), which despite influencing the ability to construct a complete and coherent situation model, does not adequately tap the specific working memory processes associated with situation model construction and updating (Radvansky & Dijkstra, 2007). However, the lack of a relation between working memory and sequencing is also in contradiction to recent research (e.g., Blything et al., 2015), which found that even simple working memory capacity (i.e., forward digit span) supported 3–7-year-olds' ability to identify the temporal relation between two events, including when the chronological order of the events did not match the order in which they were presented in the text, thus likely requiring processing beyond simple textbase recollection.

Thus, several alternative explanations for this finding are explored here. It is possible that although the sequencing task involved the storage and manipulation of information, task demands may not have been sufficient to overload working memory capacity. Events constituting each situation model were presented in chronological order, thereby avoiding the increased cognitive load induced by nonchronological presentation. Additionally, in contrast to previous research conducted with young children (e.g., Blything et al., 2015), each narrative included in the current study contained a significant temporal shift (event boundary), which is likely to have elicited the construction of a new situation model and transfer of the previous situation model to long-term memory (Radvansky & Zacks, 2014), meaning only three items needed to be maintained and integrated.

Specifically, because significant shifts in temporal or causal information can result in a new situation model being constructed (Zwaan, 1996), it is likely that previously encountered information is no longer held directly in working memory, thus freeing cognitive resources. Thus, whereas previous research that used texts describing a very limited time shift within a single sentence (e.g., *before*, *after*; Blything et al., 2015) found a relation between working memory and sequencing, it is possible that the current study did not due to the use of extended event boundaries, which enabled limitations of working memory capacity to be overcome.

Similarly, events pertaining to the same situation are incorporated into a single situation model (Radvansky & Copeland, 2006), allowing multiple events to be chunked together into a single unit and thereby increasing the amount of information that participants were able to maintain simultaneously (Daneman & Carpenter, 1980). Any or all of these factors may have lessened the cognitive load of the task such that sequencing performance was not constrained by working memory.

This observation may be further explained by the involvement of long-term memory in the encoding and retrieval of information. Although evidence supports the construction of temporally ordered representations (Claus & Kelter, 2006), it is unclear whether chronological order is encoded in situation models or reconstructed from the situation model during retrieval. It is plausible that the lack of a relation between working memory and sequencing in this study may suggest that sequencing of multiple situation models is a function of long-term memory and, therefore, does not place additional demands on working memory capacity. Indeed, previous research has found some behavioral evidence of a relation between situation model construction and long-term memory (Radvansky & Copeland, 2006), and there has been some evidence in the neuroimaging literature implicating the long-term memory network in this process (Duff & Brown-Schmidt, 2012).

Despite this, there are additional processes associated with this use of long-term memory for online language comprehension, with one being the use of working memory and cognitive control processes used to select and manipulate information. It is therefore still somewhat surprising that an effect of working memory was not evident, and thus the absence of a working memory effect may indicate limitations of the measures used. The measures of working memory may not have been sensitive enough to tap into the processes that are needed for selecting and manipulating information provided in texts with larger event boundaries (e.g., executive control processes such as the co-ordination of storage and processing, strategy selection, and operation and the activation and manipulation of information in long-term memory).

Text and Picture Sequencing

Text and picture stimuli were included in the sequencing task to allow for individual differences in verbal and visuospatial processing preferences. Although high comprehenders demonstrated better performance than low comprehenders in both tasks, no difference was found in overall performance between the text and picture conditions, nor was a relation detected between measures of verbal working memory and performance in the text tasks or between visuospatial working memory and performance in the picture tasks. However, investigation of performance on individual test items revealed that items within each level of the picture condition were not of equivalent difficulty in either the forward or backward conditions. It is likely that the pictures required participants to identify and elaborate on the scene occurring in each picture (as opposed to the text condition, where the information was explicitly stated), and thus this introduced additional variability.

Although the implications of this for the present study are relatively minor due to the materials being counterbalanced, an interesting avenue for future research is to investigate further whether there are individual differences in being able to identify and elaborate on scenes (i.e., pictures), versus elaborating on textbase information, to construct a situation model. This is potentially troublesome, as participant performance in this condition is likely to have varied as a function of the stimuli rather than sequencing or imagery ability. Despite this, significant differences between high and low comprehenders were observed when analyzing performance in the text conditions only; thus, the aforementioned conclusions may still be drawn.

Limitations and Future Research

To further determine the relation between sequencing and working memory, alternative measures of working memory should be assessed in relation to sequencing ability. For example, although the backward digit span task is generally considered to be a valid and reliable measure of verbal working memory (Conway et al., 2005), measures of additional working memory components (e.g., the central executive, the episodic buffer) may provide a more complete picture of the relation between sequencing ability and comprehension. The capacity for information to be integrated online (and, as discussed earlier, the recruitment of long-term memory processes) may be more important for situation model construction than the capacity of modality-specific components (i.e., verbal and visual subsystems). Furthermore, research has established a role for executive processes such as attention and inhibition resources in reading comprehension and situation model construction (Pike, Barnes, & Barron, 2010; for a review, see Kendeou, van den Broek, Helder, & Karlsson, 2014), and thus inclusion of these processes in future research is recommended.

Additionally, although this study provides preliminary support for sequencing being an important skill for reading comprehension, the novel measure of sequencing was developed specifically for this study. Of primary importance, therefore, is reliability testing of this measure to confirm the results reported here, along with possible developments to the measure itself (e.g., narratives of graded difficulty).

Further, although the current study found that poor comprehenders performed worse than good comprehenders on the sequencing task, the specific reasons for this are worthy of further investigation. It is possible that the poor comprehenders simply had poorer knowledge of temporal connectives than the good comprehenders did. However, the students in the current study all had age-appropriate reading abilities and were considerably older than those in previous research that found that variations in sequencing performance were driven by higher level processes such as working memory, rather than vocabulary knowledge of cue words (Blything et al., 2015). A related possibility is that differences between these two groups arose due to variations in the ability to apply these temporal cue words to initiate event boundaries, as well as the ability to use the world knowledge associated with these (e.g., that a few days later is longer than a few hours later) or organize and access this information in working and long-term memory to provide the correct temporal sequence. Explicit measurement of children's knowledge of cue words in future research would, however, allow for a more in-depth investigation of whether poor comprehenders' difficulties in sequencing indeed arise from an inability to go beyond text-based information and apply temporal information to construct and update the contents of their situation models, or are a result of lower level lexical processing.

Finally, the findings of this study do not exclude the possibility that the observed difference between comprehension groups was influenced by other high-level language skills, such as comprehension monitoring and inferencing. Accordingly, future research should extend on these findings by investigating the unique and combined contributions of these processes to reading comprehension and, furthermore, attempt to delineate performance differences when comprehension is measured at the textbase level versus the discourse level. In addition, we recommend that future research should explore the role of sequencing in reading comprehension across different developmental stages and specific populations of children. For example, investigations of comprehension and sequencing ability across developmental trajectories could help in the identification of critical time periods of skill development and allow for targeted intervention during appropriate time periods. Similarly, an investigation of these skills in populations of second-language learners and children with delayed language skills may reveal important implications for teaching and intervention.

Conclusions

This study provides preliminary evidence that high and low comprehenders differ in their ability to sequence events in narratives and supports the view that sequencing is an important skill for the comprehension of narrative texts. Additionally, this study adds new evidence to the understanding of the processing of nonchronological narratives by examining comprehension of temporal order across multiple situation models, without the requirement of reordering events within individual situation models. Although previous research has suggested that difficulties with comprehending nonchronological narratives are due to the cognitive demands of reordering events within a situation model to reflect temporal order, the present study suggests that difficulties with reordering events to construct a temporal sequence go beyond the construction of individual situation models. This study opens interesting avenues for the future investigation of the high-level processes underlying comprehension and warrants further work to develop a solid measure of sequencing to verify the results of this study. Ongoing research into the role of sequencing in comprehension is imperative to identify skills deficits and inform reading education and intervention programs.

REFERENCES

Baddeley, A. (2012). Working memory: Theories, models and controversies. *Annual Review of Psychology*, *63*, 1–29. doi:10.1146/annurev-psych-120710-100422

Barnett, V., & Lewis, T. (1994). *Outliers in statistical data* (3rd ed.). New York, NY: John Wiley & Sons.

Blything, L.P., Davies, R., & Cain, K. (2015). Young children's comprehension of temporal relations in complex sentences: The influence of memory on performance. *Child Development*, *86*(6), 1922–1934. doi:10.1111/cdev.12412

Briner, S.W., Virtue, S., & Kurby, C.A. (2012). Processing causality in narrative events: Temporal order matters. *Discourse Processes*, *49*(1), 61–77. doi:10.1080/0163853X.2011.607952

Brownstein, A.L., & Read, S.J. (2007). Situation models and memory: The effects of temporal and causal information on recall sequence. *Memory*, *15*(7), 730–745. doi:10.1080/09658210701539596

Cain, K. (2009). Making sense of text: Skills that support text comprehension and its development. *Perspectives on Language and Literacy*, *35*(2), 11–14.

Cain, K., & Oakhill, J. (2007). *Children's comprehension problems in oral and written language: A cognitive perspective*. New York, NY: Guilford.

Cain, K., Oakhill, J.V., Barnes, M.A., & Bryant, P.E. (2001). Comprehension skill, inference-making ability, and their relation to knowledge. *Memory & Cognition*, *29*(6), 850–859. doi:10.3758/BF03196414

Cain, K., Oakhill, J., & Bryant, P. (2004). Children's reading comprehension ability: Concurrent prediction by working memory, verbal ability, and component skills. *Journal of Educational Psychology*, *96*(1), 31–42. doi:10.1037/0022-0663.96.1.31

Carretti, B., Borella, E., Cornoldi, C., & De Beni, R. (2009). Role of working memory in explaining the performance of individuals with specific reading comprehension difficulties: A meta-analysis. *Learning and Individual Differences*, *19*(2), 246–251. doi:10.1016/j.lindif.2008.10.002

Claus, B., & Kelter, S. (2006). Comprehending narratives containing flashbacks: Evidence for temporally organized representations. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*(5), 1031–1044. doi:10.1037/0278-7393.32.5.1031

Conway, A.R.A., Kane, M.J., Bunting, M.F., Hambrick, D.Z., Wilhelm, O., & Engle, R.W. (2005). Working memory span tasks: A methodological review and user's guide. *Psychonomic Bulletin & Review*, *12*(5), 769–786. doi:10.3758/BF03196772

Cragg, L., & Nation, K. (2006). Exploring written narrative in children with poor reading comprehension. *Educational Psychology*, *26*(1), 55–72. doi:10.1080/01443410500340991

Daneman, M., & Carpenter, P.A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior*, *19*(4), 450–466. doi:10.1016/S0022-5371(80)90312-6

Daneman, M., & Merikle, P.M. (1996). Working memory and language comprehension: A meta-analysis. *Psychonomic Bulletin & Review*, *3*(4), 422–433. doi:10.3758/BF03214546

Duff, M.C., & Brown-Schmidt, S. (2012). The hippocampus and the flexible use and processing of language. *Frontiers in Human Neuroscience*, *6*, 1–11. doi:10.3389/fnhum.2012.00069

Eilers, L.H., & Pinkley, C. (2006). Metacognitive strategies help students to comprehend all text. *Reading Improvement*, *43*(1), 13–29.

Fenker, D.B., Waldmann, M.R., & Holyoak, K.J. (2005). Accessing causal relations in semantic memory. *Memory & Cognition*, *33*(6), 1036–1046. doi:10.3758/BF03193211

Friedman, N.P., & Miyake, A. (2000). Differential roles for visuospatial and verbal working memory in situation model construction. *Journal of Experimental Psychology: General*, *129*(1), 61–83. doi:10.1037/0096-3445.129.1.61

Friedman, W.J. (1993). Memory for the time of past events. *Psychological Bulletin*, *113*(1), 44–66. doi:10.1037/0033-2909.113.1.44

Graesser, A.C., Millis, K.K., & Zwaan, R.A. (1997). Discourse comprehension. *Annual Review of Psychology*, *48*, 163–189. doi:10.1146/annurev.psych.48.1.163

Graesser, A.C., Singer, M., & Trabasso, T. (1994). Constructing inferences during narrative text comprehension. *Psychological Review*, *101*(3), 371–395. doi:10.1037//0033-295x.101.3.371

Johnson-Laird, P.N. (1983). *Mental models: Towards a cognitive science of language, inference, and consciousness*. Cambridge, MA: Cambridge University Press.

Kelter, S., & Claus, B. (2005). How do readers deal with flashbacks in narratives. In B.G. Bara, L. Barsalou, & M. Bucciarelli (Eds.), *Proceedings of the twenty-seventh annual conference of the Cognitive Science Society* (pp. 1126–1131). Mahwah, NJ: Erlbaum.

Kelter, S., Kaup, B., & Claus, B. (2004). Representing a described sequence of events: A dynamic view of narrative comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*(2), 451–464. doi:10.1037/0278-7393.30.2.451

Kendeou, P., van den Broek, P., Helder, A., & Karlsson, J. (2014). A cognitive view of reading comprehension: Implications for reading difficulties. *Learning Disabilities Research & Practice*, *29*(1), 10–16. doi:10.1111/ldrp.12025

Kosslyn, S.M., Cave, C.B., Provost, D.A., & von Gierke, S.M. (1988). Sequential processes in image generation. *Cognitive Psychology*, *20*(3), 319–343. doi:10.1016/0010-0285(88)90002-3

Kosslyn, S.M., Margolis, J.A., Barrett, A.M., Goldknopf, E.J., & Daly, P.F. (1990). Age differences in imagery abilities. *Child Development*, *61*(4), 995–1010. doi:10.2307/1130871

Kucer, S.B. (2010). Readers' tellings: Narrators, settings, flashbacks and comprehension. *Journal of Research in Reading*, *33*(3), 320–331. doi:10.1111/j.1467-9817.2009.01416.x

Kurby, C.A., & Zacks, J.M. (2008). Segmentation in the perception and memory of events. *Trends in Cognitive Sciences*, *12*(2), 72–79. doi:10.1016/j.tics.2007.11.004

Lynch, J.S., van den Broek, P., Kremer, K.E., Kendeou, P., White, M.J., & Lorch, E.P. (2008). The development of narrative comprehension and its relation to other early reading skills. *Reading Psychology*, *29*(4), 327–365. doi:10.1080/02702710802165416

Miller, L.M., Stine-Morrow, E.A., Kirkorian, H.L., & Conroy, M.L. (2004). Adult age differences in knowledge-driven reading. *Journal of Educational Psychology*, *96*(4), 811–821. doi:10.1037/0022-0663.96.4.811

Nation, K., Clarke, P., Marshall, C.M., & Durand, M. (2004). Hidden language impairments in children: Parallels between poor

reading comprehension and specific language impairment? *Journal of Speech, Language, and Hearing Research*, *47*(1), 199–211. doi:10.1044/1092-4388(2004/017)
Neale, M.D. (1999). *Neale Analysis of Reading Ability: Manual* (3rd ed.). Melbourne, VIC, Australia: Australian Council for Educational Research.
Oakhill, J.V., & Cain, K. (2012). The precursors of reading ability in young readers: Evidence from a four-year longitudinal study. *Scientific Studies of Reading*, *16*(2), 91–121. doi:10.1080/10888438.2010.529219
Oakhill, J.V., Cain, K., & Bryant, P.E. (2003). The dissociation of word reading and text comprehension: Evidence from component skills. *Language and Cognitive Processes*, *18*(4), 443–468. doi:10.1080/01690960344000008
Oakhill, J.V., Yuill, N., & Garnham, A. (2011). The differential relations between verbal, numerical and spatial working memory abilities and children's reading comprehension. *International Electronic Journal of Elementary Education*, *4*(1), 83–106.
Ohtsuka, K., & Brewer, W.F. (1992). Discourse organization in the comprehension of temporal order in narrative texts. *Discourse Processes*, *15*(3), 317–336.
Pike, M.M., Barnes, M.A., & Barron, R.W. (2010). The role of illustrations in children's inferential comprehension. *Journal of Experimental Child Psychology*, *105*(3), 243–255. doi:10.1016/j.jecp.2009.10.006
Pyykkonen, P., & Jarvikivi, J. (2012). Children and situation models of multiple events. *Developmental Psychology*, *48*(2), 521–529. doi:10.1037/a0025526
Radvansky, G.A., & Copeland, D.E. (2001). Working memory and situation model updating. *Memory & Cognition*, *29*(8), 1073–1080. doi:10.3758/BF03206375
Radvansky, G.A., & Copeland, D.E. (2004). Working memory span and situation model processing. *The American Journal of Psychology*, *117*(2), 191–213. doi:10.2307/4149022
Radvansky, G.A., & Copeland, D.E. (2006). Memory retrieval and interference: Working memory issues. *Journal of Memory and Language*, *55*(1), 33–46. doi:10.1016/j.jml.2006.02.001
Radvansky, G.A., Copeland, D., & Zwaan, R. (2005). A novel study: Investigating the structure of narrative and autobiographical memories. *Memory*, *13*(8), 796–814. doi:10.1080/09658210444000412
Radvansky, G.A., & Dijkstra, K. (2007). Aging and situation model processing. *Psychonomic Bulletin & Review*, *14*(6), 1027–1042. doi:10.3758/BF03193088
Radvansky, G.A., & Zacks, J.M. (2014). *Event cognition*. New York, NY: Oxford University Press.
Rinck, M., Hähnel, A., & Becker, G. (2001). Using temporal information to construct, update, and retrieve situation models of narratives. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*(1), 67–80. doi:10.1037/0278-7393.27.1.67
Rinck, M., & Weber, U. (2003). Who when where: An experimental test of the event-indexing model. *Memory & Cognition*, *31*(8), 1284–1292. doi:10.3758/BF03195811
Speer, N.K., & Zacks, J.M. (2005). Temporal changes as event boundaries: Processing and memory consequences of narrative time shifts. *Journal of Memory and Language*, *53*(1), 125–140. doi:10.1016/j.jml.2005.02.009
Tapiero, I. (2007). *Situation models and levels of coherence: Toward a definition of comprehension*. New York, NY: Erlbaum.
Trabasso, T., Secco, T., & van den Broek, P. (1984). Causal cohesion and story coherence. In H. Mandl, N.L. Stein, & T. Trabasso (Eds.), *Learning and comprehension of text* (pp. 83–111). Hillsdale, NJ: Erlbaum.
Trabasso, T., & van den Broek, P. (1985). Causal thinking and the representation of narrative events. *Journal of Memory and Language*, *24*(5), 612–630. doi:10.1016/0749-596X(85)90049-X
van den Broek, P., Pugzles-Lorch, E., & Thurlow, R. (1996). Childrens' and adults' memory for television stories: The roles of causal factors, story-grammar categories, and hierarchical level. *Child Development*, *67*(6), 3010–3028. doi:10.2307/1131764
van Dijk, T.A., & Kintsch, W. (1983). *Strategies of discourse comprehension*. New York, NY: Academic.
Yuill, N., & Oakhill, J. (1991). *Children's problems in text comprehension: An experimental investigation*. Cambridge, UK: Cambridge University Press.
Zacks, J.M., Speer, N.K., & Reynolds, J.R. (2009). Segmentation in reading and film comprehension. *Journal of Experimental Psychology: General*, *138*(2), 307–327. doi:10.1037/a0015305
Zwaan, R.A. (1996). Processing narrative time shifts. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*(5), 1196–1207. doi:10.1037/0278-7393.22.5.1196
Zwaan, R.A., & Radvansky, G.A. (1998). Situation models in language comprehension and memory. *Psychological Bulletin*, *123*(2), 162–185. doi:10.1037/0033-2909.123.2.162

Submitted June 22, 2016
Final revision received February 9, 2017
Accepted February 9, 2017

BETHANIE GOULDTHORP (corresponding author) is a lecturer in the School of Psychology and Exercise Science and a researcher in the Project KIDS Neurocognitive Development Research Program at Murdoch University, Perth, Western Australia; e-mail b.gouldthorp@murdoch.edu.au. Her research interests relate broadly to the cognitive processes that underlie narrative and discourse-level comprehension, particularly in relation to the use of mental imagery and memory representations; the neurobiological circuitry that subserves these processes; and the application of this knowledge to understanding individual differences in the development and use of language.

LIA KATSIPIS was a doctoral student in the School of Psychology and Exercise Science and the Project KIDS Neurocognitive Development Research Program at Murdoch University, Perth, Western Australia, when this study was conducted, and recently received her PhD; e-mail lia.katsipis@gmail.com. Her research interests focus on investigating the nature of the mental representation that underlies successful reading comprehension, with a focus on the contribution of higher level cognitive functions and nonverbal skills such as visual imagery, knowledge integration, attention, and inhibition.

CARA MUELLER was a graduate student in the School of Psychology and Exercise Science at Murdoch University, Perth, Western Australia, when this study was conducted; e-mail cara.mueller@murdoch.edu.au. She is now completing postgraduate study in clinical psychology.

Supporting Information

Additional supporting information may be found in the online version of this article:

- Appendix A: Example Stimuli
- Appendix B: Verbatim Instructions Provided for the Sequencing Task