Chapter 4

Does the Component Processes Task Assess Text-Based Inferences Important for Reading Comprehension? A Path Analysis in Primary School Children

Abstract

Using a component processes task that differentiates between higher-level cognitive processes of reading comprehension provides important advantages over commonly used general reading comprehension assessments. The present study contributes to further development of such a task by evaluating the relative contributions of the components (i.e., text memory, text inferencing, and knowledge integration) and working memory to general reading comprehension using path analyses. A component processes task (based on August et al., 2006), was administered to 173 third- and fourth-grade children. Results indicated that the text-inferencing and knowledge-integration components were dependent on explicit text memory. As hypothesized, the text-inferencing component did not assess inferential processes related to reading comprehension. Knowledge integration was the only component of the component processes task that directly contributed to reading comprehension. Future research should focus on finding ways to ensure that the text-inferencing component taps into processes important for deep text comprehension.
Introduction

In recent years there has been an expanded interest in the development of a reading-based component processes task (CPT\(^1\); Hannon & Daneman, 2001; Hannon & Frias, 2012). The purpose of this task is to differentiate between higher-level cognitive processes of reading comprehension, which contributes to the increasing need to address individual differences in reading performance (August et al., 2006). Moreover, the CPT offers certain advantages over global standardized measures of reading comprehension in that it is theoretically motivated and practical to administer (Hannon & Daneman, 2001).

The idea underlying the CPT is based on a paradigm that was originally developed by Potts and Peterson (1985) to study incorporation of newly learned information into the readers’ world knowledge. In the Potts and Peterson paradigm, readers study a three-sentence paragraph in which the relations among two real and three artificial terms are described, for example, “A JAL is larger than a TOC. A TOC is larger than a PONY. A BEAVER is larger than a CAZ.” (Potts & Peterson, 1985). The described relations among the items (based on their relative sizes) represent a linear ordering (e.g., JAL > TOC > PONY > BEAVER > CAZ). Importantly, to construct this ordering the reader is required to access and integrate both text-based information (e.g., “A TOC is larger than a PONY”) and prior knowledge (e.g., “a pony is larger than a beaver”), as not all relations are stated explicitly. True-false test statements are used to differentiate between underlying component processes. Text-memory (TM) statements can be answered on the basis of explicitly presented text information (e.g., “A JAL is larger than a TOC”). Text-inferencing (TI) statements test information that can be deduced from the text (e.g., "A JAL is larger than a PONY" can be deduced from the statements "A JAL is larger than a TOC" and "A TOC is larger than a PONY"). Both types of text-based statements do not require prior knowledge. This is left to knowledge-integration (KI) statements, which tests information that can only be deduced by using existing knowledge in conjunction with presented text information (e.g., “A TOC is larger than a BEAVER” can be deduced from combining the presented text information “A TOC is larger than a PONY” with existing knowledge that ponies are larger than beavers).

\(^1\) In the present article, “component processes task” (CPT) refers to all tasks based on the Potts & Peterson (1985) paradigm that are used to differentiate between cognitive component processes underlying reading comprehension, including for example the Diagnostic Assessment of Reading Comprehension (DARC; August et al., 2006).
Researchers have confirmed, using correlational analyses, factor analyses, and structural equation analyses, that the different types of statements tap into two different resources as theorized: text-based information and prior knowledge (Hannon & Daneman, 2001; Hannon & Frias, 2012; Hannon, 2012; Potts & Peterson, 1985). In addition, research has shown that the KI component predicts readers’ ability to construct bridging inferences (Singer & Ritchot, 1996), which is an important skill for reading comprehension. According to Hannon and Daneman (2001), not only the KI component but all components as measured by the paradigm capture aspects of reading comprehension ability. Building on Hannon and Daneman’s (2001) attempt to develop an assessment instrument of higher-level component processes of reading comprehension, the Potts and Peterson paradigm has become a popular basis for other CPT’s (e.g., August et al., 2006; Hannon & Frias, 2012). In this article, we argue that although there is evidence that the CPT differentiates between different cognitive resources and processes, at least some of these processes do not seem to require comprehension-related activities, and hence not necessarily contribute to reading comprehension. This poses a serious challenge to the CPT presenting itself as an assessment instrument developed to differentiate between multiple components that are all sources of individual differences in reading comprehension (Hannon & Daneman, 2001). Our concern focuses on the assumed role of inferencing in the CPT.

A considerable amount of both developmental and adult research literature has shown that inference making skill is one of the main sources of individual differences in reading comprehension performance (e.g., Barnes, Dennis, & Haefele-Kalvaitis, 1996; Cain, Oakhill, & Bryant, 2004; Long, Oppy, & Seely, 1994; Oakhill, 1982). It has been proposed that, especially connecting incoming text information to previous text information (i.e., text-based inferences) and the integration of text information with prior knowledge (i.e., knowledge-based inferences) contribute to the construction of a rich, coherent, non-linguistic mental representation required for deep-level text comprehension, a so-called situation model (e.g., McNamara & Magliano, 2009; Zwaan, Langston, & Graesser, 1995; Zwaan & Radvansky, 1998). We contend, however, that the activity of inferential processing related to the construction of a situation model in order to support text comprehension, is not necessarily reflected by the CPT’s test statements. That is, the TI component seems to involve ‘inferential’ processes that are not directly related to reading comprehension, reflecting cognitive skills like logical reasoning instead (i.e., A > B, B > C, so A > C). Arguably, a five-term linear ordering constructed from the text is a linguistic, mathematical mental representation, rather than a rich perceptual mental representation of the described...
situation. Accordingly, it can be argued that only the KI component entails at least some
comprehension-related inferential processing, because it requires readers to move
beyond the text and supplement their mental representation with prior perceptual
experiences of familiar items.

Support for our argument comes from research administering the CPT in
conjunction with general reading comprehension tests. For example, the component
scores of the original Potts and Peterson task (Potts & Peterson, 1985) were only
moderately correlated to general reading comprehension, whereas they were strongly
correlated with deductive and analytical reasoning skill (Hannon & Daneman, 2001;
Exp 1). Nearly 60% of the participants reported answering the statements by
memorizing and rehearsing a simple linguistic mnemonic for the five-term linear
ordering (e.g., JTPBC for JAL > TOC > PONY > BEAVER > CAZ). Further, Hannon
and Daneman (2001; Experiment 1) argued that the original CPT was not complex
enough to capture the processes that are crucial for reading comprehension. After
increasing the complexity of the task (by including more semantic features and
increasing the number of test statements; Experiment 2), they indeed showed a stronger
correlation to reading comprehension (however yielding comparable correlations to
analytical reasoning) and a larger amount of explained variance. Although a difficult
task is more likely to tap into complex cognitive processes, this does not necessarily
imply that actually comprehension-related reading processes are captured. The five-term
orderings constructed from the passages can, presumably, still be memorized and
rehearsed as a linguistic mental representation (e.g., a mnemonic) rather than a
perceptually rich non-linguistic mental representation. It then is not surprising that for
the complex version, the KI component remained to be the best predictor of reading
comprehension performance (Hannon & Daneman, 2001).

Further support for our argument comes from the fact that the TI component
does not seem to account for any unique variance in general reading comprehension
This suggests that not all components as assessed by the CPT are sources of individual
differences in reading comprehension. Hannon’s cognitive components-resource model
(2012) shows that the CPT’s text-based components together (i.e., TM and TI) have an
indirect effect on reading comprehension through the KI component. This model,
however, does not differentiate between the effects of TM and TI. Based on results from
erlier studies (Hannon & Daneman, 2001; Hannon & Frias, 2012), we hypothesize that
this indirect effect is caused by the TM component alone, and that the TI component
does not account for unique proportions of variance of reading comprehension. If this is
the case, one could wonder to what extent the TI component provides an added value in the CPT.

To investigate the concerns described above, a path model (depicted in Figure 1a) showing the hypothesized relative contributions of the CPT components and working memory to reading comprehension performance was tested. The critical aspect of this model is that consistent with our reasoning, it does not contain a direct path from TI to reading comprehension. Only a direct path from KI to reading comprehension is expected. Furthermore, based on Hannon's (2012) findings, a direct path from working memory to reading comprehension was included in the model. A direct path from working memory to TM reflects the importance of keeping information active during reading. Only indirect paths from working memory to TI and KI, through TM, are

Figure 1a. Hypothesized model.

Figure 1b. Model 2, including all direct and indirect pathways.
included, indicating the necessity of memorizing literal text statements for correctly answering TI and KI statements. The hypothesized model was tested against a model including all direct and indirect effects (Figure 1b).

Finally, it could be argued that the TI component in fact does assess inferencing skills important for reading comprehension, but this does not surface simply because readers are not required to comprehend the paragraph at a deeper level. To exclude this alternative explanation, the three statements containing crucial information for constructing the five-term ordering were integrated into longer narrative-like texts similar to how this is done in the Diagnostic Assessment of Reading Comprehension (DARC; August et al., 2006). These texts required the reader to make elaborative inferences for deep-level comprehension (for an example see Appendix C). Practically, this makes the task more ecologically valid as it more closely resembles the regular reading experience. As a result, if the hypothesized path model appears to be a good fit of the data, it can be concluded that the TI component assesses a cognitive skill that does not contribute to deep-level comprehension and, presumably, TI statements are answered based on other types of processing instead, such as relying on logical reasoning skills. Additionally, the present study extends previous research in two ways. First, building further upon Hannon (2012), the present study is—to our knowledge—the first to investigate the relative contributions of three CPT components (i.e., TM, TI, and KI) individually to reading comprehension within a single model. Second, the present study applies the CPT to a yet unexplored target group. Rather than focusing on populations such as adults (Hannon & Daneman, 2001), English language learners (August et al., 2006; Francis et al., 2006), and preschoolers (Hannon & Frias, 2012), our study is the first to investigate the relative contributions of the CPT components and working memory to general reading comprehension performance in primary school children; an age group which, given the importance assigned to reading comprehension instruction and assessment at the primary school level (National Reading Panel, 2000), represents the ultimate target population for a task like the CPT.

Method

Participants

The study contained data from 173 children (92 boys) from Grades 3 and 4 of four regular primary schools in the Netherlands (age range 8–10 years, \( M = 9.08, SD = .67 \)). Children with (diagnosed) dyslexia as indicated by school records (\( n = 17 \)) were excluded from the study. All participants were fluent Dutch speakers and had grade-appropriate decoding skills. Children’s legal guardians provided written informed
consent based on printed information about the purpose of the study. Participation was voluntary and children received a small gift after the experiment.

**Materials**

**Component processes task.** Our CPT, used to assess the component processes, is a modified version of the DARC (August et al., 2006). The DARC was specifically designed to minimize decoding and language demands and is, therefore, a suitable task for primary school children. For the present study, the task was slightly modified: it was translated into Dutch, using only familiar words for children in Grade 3 and 4 as indicated by their school teachers, and names of the artificial terms were changed so that they were orthographically transparent and had no meaningful lexical neighbors.

The CPT used in the present study consisted of four short passages. In each passage relations among two real and three artificial terms were described from which a five-term linear ordering could be constructed by using both text information and world knowledge (e.g., MIPPER < BICYCLE < CAR < PLORT < VASKER). Additionally, sentences describing relations among the five terms were incorporated into a narrative depicting a particular story event, including multiple narrative dimensions (i.e., character, time, space, causation) to encourage children to construct a rich mental representation (see Appendix C for a story example). To establish and maintain coherence, children were required to engage in inferential processes. Each narrative was followed by 12 true-false statements of three different types; four text-memory statements, three text-inferencing statements, and four knowledge-integration statements (see Appendix C). To reduce the probability of a correct response through guessing, ‘I don’t know’ answer options were added for each statement. The ‘I don’t know’ responses were treated as incorrect. Accuracy scores were calculated for the three statement types.

**Working memory.** A reading span test (Daneman & Carpenter, 1980) was administered as a measure of verbal working memory (Carpenter & Just, 1989; Just & Carpenter, 1992). Participants were required to read aloud a set of sentences. After each set, participants reported back the final word of each sentence of the most recent set. After every three sets, the number of sentences within a set was increased by one until participants failed to recall one or more words on at least two out of three sets. Participants’ reading span score was defined by the number of sentences of the last set in which all final words were recalled correctly. Half a point was subtracted when only one out of three sets was completed correctly. For example, when a participant correctly
completed all three two-sentence sets and only one three-sentence set, the test was terminated and a score of 2.5 was obtained. Correctly completing two four-sentence sets and no five-sentence sets resulted in a score of 4. The test started with two practice sets of two sentences and ended with a maximum of five sentences per set, resulting in a reading span score between 1.5 and 5.

**General reading comprehension.** Grades 3 and 4 versions of the standardized CITO (Institute for Educational Measurement; 2010) Reading Comprehension Test were used to measure children’s reading comprehension skills. This test is part of the standard Dutch pupil monitoring system and is designed to determine general reading comprehension level in primary school children. It contains two modules, each consisting of a text and 25 multiple-choice questions. The questions were designed to tap both the text-base and situation model representation that can be constructed from the text (e.g., Kintsch, 1988) and pertained to either the word, sentence, or text level. Normed proficiency scores were obtained by rescaling students’ raw test scores on the 50 items. The rescaling procedure enabled us to compare the results between children from different grades (i.e., Grades 3 and 4). The internal consistency coefficient of the tests was high, with Cronbach’s alpha’s not less than .85 (Feenstra et al., 2010).

**Procedure**

The CPT was administered in a normal class setting. Children received a booklet containing the stories and test statements. They were instructed to read the stories at their own pace. After a story was read, children turned the page to answer the test-statements. They were not allowed to look back. Children got 45 minutes to complete the booklet. The reading span test was administered individually in a quiet room at school. Children sat at a computer and completed the reading span test at their own pace, which took about 10 to 20 minutes, depending on the number of trials completed. Approximately half of the children completed the reading span test before the CPT, whereas the other half completed the reading span test after the CPT. Children never completed both tests on the same day. CITO reading comprehension scores were retrieved from school administrations.

**Statistical Analyses**

Path analyses using LISREL 9.20 were performed to examine whether the hypothesized model fitted the data and to further explore direct and indirect effects of CPT components and working memory on general reading comprehension. The overall model fit was assessed by chi-square ($\chi^2$), root mean square error of approximation
(RMSEA), and comparative fit index (CFI). A non-significant chi-square statistic, a RMSEA < .05, and CFI > .95 together indicate a strong fit of the data with the model, whereas a RMSEA < .08 and a CFI > .90 indicate an adequate fit (Hu & Bentler, 1999; Kline, 2005). The two path models, as depicted in Figure 1a and 1b are nested and can be compared statistically.

**Results**

**Descriptive Statistics**

Table 1 shows means, standard deviations, and minima and maxima for each measure. Mean scores on the standardized test for reading comprehension indicate overall average performance. Table 2 shows that all variables are significantly correlated. As found by previous studies (e.g., Hannon & Daneman, 2001; Potts & Peterson, 1985), the TM component is strongly correlated with TI and KI, whereas these last two are only moderately correlated to each other ($r = .37$). KI is strongly correlated with reading comprehension ($r = .48$), whereas the other components are moderately correlated with reading comprehension. The working memory measure (i.e., sentence span task) appears to be weakly correlated to all other measures.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Processes Task</td>
<td></td>
</tr>
<tr>
<td>Text memory (TM)</td>
<td>71.9</td>
</tr>
<tr>
<td>Text inferencing (TI)</td>
<td>70.6</td>
</tr>
<tr>
<td>Knowledge integration (KI)</td>
<td>56.5</td>
</tr>
<tr>
<td>Additional measures</td>
<td></td>
</tr>
<tr>
<td>Reading comprehension (max = 147)</td>
<td>20.6</td>
</tr>
<tr>
<td>Sentence span (max = 5)</td>
<td>2.3</td>
</tr>
</tbody>
</table>

*Means, standard deviations, and ranges for the components are reported as percentages.*
Table 2
Correlations among CPT components and additional measures

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Text memory</td>
<td>—</td>
<td>.52***</td>
<td>.55**</td>
<td>.38***</td>
<td>.28***</td>
</tr>
<tr>
<td>2. Text inferencing</td>
<td>—</td>
<td>.37**</td>
<td>.32***</td>
<td>.16*</td>
<td></td>
</tr>
<tr>
<td>3. Knowledge integration</td>
<td>—</td>
<td>.48***</td>
<td>.20**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Reading comprehension</td>
<td>—</td>
<td>.24**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Sentence span</td>
<td>—</td>
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</tbody>
</table>

Note. *p < .05. **p < .01. ***p < .001.

The final model fitted the data well; $\chi^2(5) = 8.40, p = .135, \text{CFI} = .98, \text{RMSEA} = .06$, explaining 25% ($R^2 = .25$) of variance of reading comprehension. The final model confirmed the hypothesized model (Figure 1a), indicating that indirect effects of working memory on TI and KI were fully mediated by TM, and importantly, KI was the only CPT component predicting unique variance of reading comprehension. As hypothesized, TI did not explain any variance in reading comprehension.

![Figure 2](image_url) *Figure 2. Final model, including the standardized estimates of the variables influencing reading comprehension performance, the significant pathways are indicated with an asterisk, *p < .05, **p < .001.*
Discussion

The present study sought to demonstrate that the TI component, as assessed by the CPT, assesses a cognitive skill that does not necessarily contribute to reading comprehension. To our knowledge, this is the first study to include the individual components of the CPT in a single path model and investigate the relative contributions of the CPT components and working memory to general reading comprehension performance in primary school children. In general, our results are consistent with previous findings from CPT studies focusing on adult readers (Hannon & Daneman, 2001; Hannon, 2012), second language learning children (August et al., 2006; Francis et al., 2006), and preschoolers (Hannon & Frias, 2012). We replicated the patterns of correlations among the three CPT components, working memory, and general reading comprehension (Hannon & Daneman, 2001; Potts & Peterson, 1985), indicating that the CPT used in the present study is valid and suitable for primary school children. Furthermore, our hypothesized model explained the present data best, from which we draw several conclusions.

The first important finding is that, according to the present model, the TI component does not contribute to general reading comprehension performance. Despite the fact that this finding does not contradict results reported in previous studies, which have shown that the TI component does not account for any unique variance in general reading comprehension performance over and above TM (Hannon & Daneman, 2001; Hannon & Frias, 2012), so far, this has not been demonstrated directly within a single model. The absence of a path from TI to reading comprehension, provides converging evidence for our argument that the TI component, as assessed by the CPT, does not seem to capture the type of inferential processing that is associated with reading comprehension. The direct path from TM to TI, combined with the absence of a direct path from working memory to TI, indicates that the TI component requires cognitive processing based on memorized text information. Obviously, if readers, irrespective of their working memory capacity in general, fail to memorize explicit text information (TM), it is impossible to answer TI statements correctly. Presumably, using the memorized text information, readers rely on processes like logical reasoning for answering the TI statements (Nunes et al., 2007). This would be in accordance with the strong correlation between the TI component and performance on reasoning tasks found for the original Potts and Peterson paradigm (Hannon & Daneman, 2001), and the finding that logical reasoning skill is relatively independent of working memory (Nunes et al., 2007).
Importantly, by using more narrative-like texts, we excluded the possibility that these results were due to using texts that do not require readers to construct a mental representation during reading and, therefore, TI test statements cannot assess comprehension-related inferential processes. Although narratives were purposefully developed to encourage readers to construct a rich and coherent mental representation, however, the TI test statements still did not seem to reflect this. Therefore, to enable TI test statements to assess the constructive memory processes (semantic integration and text-based inferencing) that are not necessarily dependent on the availability of general knowledge, it may be useful to include situational aspects from the narrative in the TI test statements. For example, after reading “the car crashed into the bus” and “the bus was near the crossroads”, it is possible to infer that “the car was near the crossroads”. To do this, the reader does not need specific prior knowledge but is required to construct a coherent perceptual representation of the described story situation (Oakhill, 1982). Future research could investigate how the TI test statements can effectively assess text-inferencing processes that are important for the construction of a rich and coherent mental representation of the described situation.

Another important finding is that, according to the final model, the KI component is the only predictor of reading comprehension. This is in accordance with previous research showing that KI was the most important component in explaining variance in both adults’ (Hannon & Daneman, 2001) and preschoolers’ (Hannon & Frias, 2012) comprehension skills, and was a good predictor of readers’ ability to generate bridging inferences (Singer & Ritchot, 1996). The model suggests that TM only indirectly contributes to reading comprehension, through the KI component. The direct path of KI to reading comprehension, combined with the absence of direct paths from TI and TM to reading comprehension, seems to suggest that the KI component is the only component that assesses processes important for comprehension of text. Related to this, the indirect path from working memory to KI, through TM, indicates that KI is dependent on memorizing textual information as captured by the TM component. If the reader fails to keep explicit information active during reading, it is impossible to correctly answer the KI statements.

Finally, after taking into account all the variance of reading comprehension that is explained by the CPT, working memory still accounts for a significant amount of variance in reading comprehension. Consistent with Hannon’s (2012) findings, a model including both direct and indirect paths from working memory to reading comprehension fitted the data significantly better than a model only containing indirect paths. This seems to be the case for both children (present study) and adult readers.
(Hannon, 2012), even though it has been shown that working memory is particularly important to young children’s language comprehension (Hannon & Frias, 2012). Our findings suggest that the CPT does not capture all working memory aspects that are required for reading comprehension. A future version of the CPT may benefit from components tapping into the essence of the story, rather than being highly dependent on text memory. It should provide coverage of comprehension-related inference and integration processes that are directly related to working memory.

To conclude, the present study provides further insight into the CPT’s potential as an assessment of individual differences in component processes of reading comprehension. It seems that the TI component, in its current form, assesses inferential processes that are not directly related to reading comprehension. It is, therefore, important that future research further investigates this component and potentially adapts or refines the test statements to make the CPT a more efficient measure of reading comprehension components. Together, our study aims to contribute to the development of the CPT with respect to both its content and its suitability for assessing primary school children. Compared to currently used general reading comprehension assessments, the CPT provides important advantages in its potential to explain individual differences in underlying component processes.