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The Role of Passage Topic Knowledge in Typical and Poor Comprehenders' Recall

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THE ROLE OF PASSAGE TOPIC KNOWLEDGE IN TYPICAL AND POOR
COMPREHENDERS' RECALL

A Dissertation

Presented to

the Faculty of Social Sciences

University of Denver

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

by

Chelsea E. Meenan

August 2015

Advisor: Janice M. Keenan

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Abstract

This dissertation examines the role of topic knowledge (TK) in comprehension among typical readers and those with Specifically Poor Comprehension (SPC), i.e., those who demonstrate deficits in understanding what they read despite adequate decoding. Previous studies of poor comprehension have focused on weaknesses in specific skills, such as word decoding and inferencing ability, but this dissertation examined a different factor: whether deficits in availability and use of TK underlie poor comprehension. It is well known that TK tends to facilitate comprehension among typical readers, but its interaction with working memory and word decoding is unclear, particularly among participants with deficits in these skills. Across several passages, we found that SPCs do in fact have less TK to assist their interpretation of a text. However, we found no evidence that deficits in working memory or word decoding ability make it difficult for children to benefit from their TK when they have it. Instead, children across the skill spectrum are able to draw upon TK to assist their interpretation of a passage. Because TK is difficult to assess and studies vary in methodology, another goal of this dissertation was to compare two methods for measuring it. Both approaches score responses to a concept question to assess TK, but in the first, a human rater assigns a score whereas in the second, a computer algorithm, Latent Semantic Analysis (LSA; Landauer & Dumais, 1997) assigns a score. We found similar results across both methods of assessing TK, suggesting that a continuous measure is not appreciably more sensitive to variations in

knowledge than discrete human ratings. This study contributes to our understanding of how best to measure TK, the factors that moderate its relationship with recall, and its role in poor comprehension. The findings suggest that teaching practices that focus on expanding TK are likely to improve comprehension across readers with a variety of abilities.

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Chapter One: Introduction

The Role of Passage Topic Knowledge in Typical and Poor Comprehenders' Recall

The main objective of comprehension is to allow readers to acquire knowledge, but ironically, to gain new knowledge readers must already have some information about the topic. This is because comprehension requires the integration of one's prior knowledge with the text to create a mental model of the situation (Kintsch, 1988, 1998). Knowledge is involved in identifying words, forming ideas, and connecting ideas in building a mental model. It is therefore reasonable to suspect that those who struggle with comprehension may do so in part because they lack the necessary knowledge. In addition, it is possible that even when a comprehender has knowledge available, there may be resource limitations that can affect how readily the knowledge can be accessed and used in comprehension. Possible sources for these limitations are decoding skill and working memory (WM). The purpose of this dissertation therefore is to explore both the role of passage topic knowledge (TK) in explaining comprehension difficulties and the degree to which its use is constrained by WM and decoding skill.

Both general knowledge, which reflects widespread experience about how the world operates, and specific topic knowledge contribute to comprehension (Best, Floyd, & McNamara, 2008; McNamara & Kintsch, 1996; Rawson & Van Overschelde, 2008; Recht & Leslie, 1988; Spilich, Vesonder, Chiesi, & Voss, 1979). The current study

investigates the relationship between these two types of knowledge, but focuses primarily on TK that is directly related to the specific concepts or ideas discussed in a text.

Background TK decreases the difficulty of comprehension because it enables readers to draw upon existing knowledge to facilitate bottom-up word decoding (Priebe, Keenan, & Miller, 2012) as well as top-down processes, which help readers to interpret meaning and organize ideas (Hambrick, 2003; Miller & Keenan, 2009; Rawson & Kintsch, 2002). For example, in a passage about Lewis and Clark, readers encounter the following sentence: “They became acquainted with a sixteen-year old Indian woman and adopted her as their primary guide.” A reader with knowledge about Sacajawea will comprehend this sentence more readily than a reader without that knowledge. When a reader does not have sufficient knowledge of the subject, the difficulty of comprehending increases (Bartlett, 1932; Bransford & Johnson, 1972; McNamara & Kintsch, 1996), particularly for difficult texts (McNamara, Kintsch, Songer, Kintsch, 1996). Yet many studies overlook TK in favor of investigating deficits in cognitive skills as the source of comprehension difficulties (Cain & Oakhill, 2006). Thus, one of the goals of this dissertation is to investigate whether shortages in TK contribute to the difficulties of those who are identified as having general comprehension deficits.

Comprehension requires the coordination of several component skills, so the present study investigates how the use of TK is influenced by two other comprehension abilities: word decoding and WM. We do this in a large sample of children with varying word decoding skills and WM skills as well as a subgroup of struggling readers who demonstrate relative strengths in decoding yet have difficulty comprehending. These children are known as specifically poor comprehenders (SPCs) and their poor

comprehension is thought to be a reflection of weaknesses in oral language. Research on this subgroup of poor comprehenders has revealed deficits in areas including working memory (Yuill, Oakhill, & Parkin, 1989) and inference making (Cain & Oakhill, 1999; Cain, Oakhill, Barnes, & Bryant, 2001), among others (Cain, 2003; Cain & Oakhill, 1996; Ehrlich, Remond, & Tardieu, 1999; Oakhill, Hartt, & Samols, 2005). We examine these children to assess whether their cognitive deficits constrain their ability to use TK for comprehension.

Topic Knowledge and Poor Comprehension

TK provides a framework on which to organize textual information, facilitating several steps involved in the comprehension process (McNamara & Kintsch, 1996; Rawson & Van Overschelde, 2008; Recht & Leslie, 1988; Spilich, Vesonder, Chiesi, & Voss, 1979). Knowledge assists low-level word decoding (Priebe et al., 2012), and higher-level processes such as inference-generation (Marr & Gormley, 1982) and identification of main ideas (Afflerbach, 1990), aiding comprehension. Without sufficient TK to draw from, even typical readers struggle to understand what they read (Chiesi, Spilich, & Voss, 1979; Spilich, Vesonder, Chiesi & Voss, 1979).

Spilich, Vesonder, Chiesi, and Voss (1979) investigated the effect of TK on participants' comprehension for a story about a baseball game. TK for baseball was assessed by having participants complete an aptitude test about the terminology, rules, and procedures of the game. Results indicated that individuals with high TK about baseball recalled more information than did participants with low TK, and importantly, they also recalled qualitatively different types of information. High TK participants recalled more propositions about the events that affected the goal of winning the game,

such as getting runners on base and advancing them toward home, whereas low TK individuals tended to remember irrelevant information about the game setting. This difference suggests that TK affects how ideas in a text are processed and encoded, which leads to better recall. Evidence supporting this interpretation comes from a similar series of studies on high and low TK individuals by Chiesi, Spilich, and Voss (1979).

Individuals with high baseball TK required less information to determine whether they had previously heard a particular baseball description, were quicker to recognize changes in game information, especially changes that affected the goal structure of the game, and were better able to keep track of event sequences that most closely related to the goals of the game.

Those who struggle to understand what they read are also likely to read less, limiting their opportunities to acquire knowledge. Having less TK leads children from disadvantaged socioeconomic backgrounds to demonstrate poorer comprehension as well as weaknesses in learning new words (Kaefer, Neuman & Pinkham, 2015). For this reason, poor TK has been named as a contributor to comprehension deficits (Kamhi, 2009) and to achievement gaps between children from advantaged and disadvantaged economic backgrounds (Chall, Jacobs & Baldwin, 1990; Kaefer, Neuman & Pinkham, 2015). Given the considerable facilitative role of TK, the current study asks whether poor comprehenders have a general deficit in TK.

TK and Cognitive Abilities

Comprehension requires readers to actively construct a mental representation of the passage by inferring relationships between textual idea units, attending to incoming information, synthesizing it with existing TK, and interpreting meaning (Catts, 2009).

This involves the coordination of bottom-up skills, such as word decoding, as well as the top-down influence of prior knowledge (Kintsch, 2005). When readers have weak word decoding, they struggle to identify individual words and comprehension necessarily suffers (Perfetti, 1985). But not only do poor decoders show worse comprehension overall, they also differ in the type of information they recall. Poor decoders have fewer resources for connecting ideas together and thus show the greatest deficits for information that is central to the meaning of a text (Miller & Keenan, 2009; Smiley, Oakley, Worthen, Campione, & Brown, 1977).

Miller and Keenan (2009) investigated whether TK could improve poor decoders' recall of central information for a reading passage about Amelia Earhart. These authors found that when readers did not have TK, poor decoders showed the greatest deficits in recalling information that was most central to the meaning of the text, but when they did have TK, relative deficits in central information for poor decoders were eliminated. Interestingly, this compensatory effect of TK only occurred among poor decoders. There were no differences in recall of central information for good decoders with and without TK.

Other studies have also investigated the relation between reading ability and TK on comprehension questions, rather than recall, and instead found that those with greater reading skill are able to use TK to a greater advantage. Adams, Bell and Perfetti (1995) found an interaction between TK and reading skill, such that there was a greater effect of TK among high skilled readers. Children were categorized into high and low "reading skill" groups (above the 60% and below the 40%, respectively) as assessed by the California Achievement Test. This test contains both a vocabulary and comprehension

assessment, but it is unclear which scores were used to classify participants. The investigators measured performance across two passages; one was considered domain specific (a passage about football) and the other was considered domain general (a passage about rescuing a child from a fire). Performance on comprehension questions was compared among four groups differing in football knowledge (high/low) and reading skill (high/low) using a series of ANOVAs to establish whether TK interacts with reading ability. The authors found a complex relationship between reading skill and TK.

Readers with high skill/high knowledge performed the best overall and did much better than those with high skill/low knowledge, indicating that TK increased comprehension performance among those with high reading ability. However, the low skill groups performed similarly on the domain-specific passage, regardless of knowledge. This means that TK's influence may partially depend on the reader's skill level; high skill readers are able to use TK to a greater advantage than readers with lower skills (Adams et al., 1995). However, the sample size used in this study was small ($N = 24$) and so results should be interpreted with caution. The question remains as to the extent to which decoding constrains readers' abilities to benefit from TK (as in Adams et al., 1995), or whether poor readers can use TK to improve comprehension (as in Miller & Keenan, 2009).

The cognitive components of comprehension tend to correlate with each other; TK, general world knowledge, word decoding, and working memory (WM) ability, as we will show, all are positively correlated. While word decoding ability is only directly relevant for passages that require children to read, the correlation between word decoding and other important components of comprehension, namely general knowledge, led us to

control for word decoding and therefore associated abilities across both reading and listening passages. In the case that we find an interaction between word decoding and TK for a listening passage, this would reflect the influence of other variables that are related to word decoding. The question arises as to whether discrepancies across studies in the effects of TK in compensating for decoding deficits could reflect differences across samples in other cognitive abilities. For example, in the Adams et al. (1995) study, participants with better “reading ability” may have had more general knowledge or better WM, allowing them to draw on their TK to greater effect. The low skill group likely had poorer word decoding and WM ability, so even when they had TK, they may not have had the WM capacity to use it after decoding the words in the passage. There is some evidence to support the idea that WM limits the degree to which TK influences comprehension (Hambrick & Engle, 2002).

WM is one of many factors known to differ across comprehension groups (Carretti, Cornoldi, De Beni & Romanò, 2005; Nation, Adams, Bowyer-Crane & Snowling, 1999). WM is involved in retrieving TK from memory, integrating it with passage content, resolving conflicting information, and generating inferences (Kintsch, 1988; Kintsch, 1994; Marr & Gormley, 1982; McNamara, Kintsch, Songer, & Kintsch, 1996; Rawson & van Overschelde, 2008; Recht & Leslie, 1988; Spilich et al. 1979; Voss, Vesonder, & Spilich, 1980). While several studies investigating the relationship between knowledge and WM have neglected to report on the interaction between the two (Britton, Stimson, Stennett, & Gülgöz, 1998; Haenggi & Perfetti, 1992, 1994), there is some evidence that TK has a greater effect for those with better WM. In two separate studies,

researchers investigated whether TK differently affects comprehension among those with high and low WM capacity (Hambrick & Engle, 2002; Hambrick & Oswald, 2005).

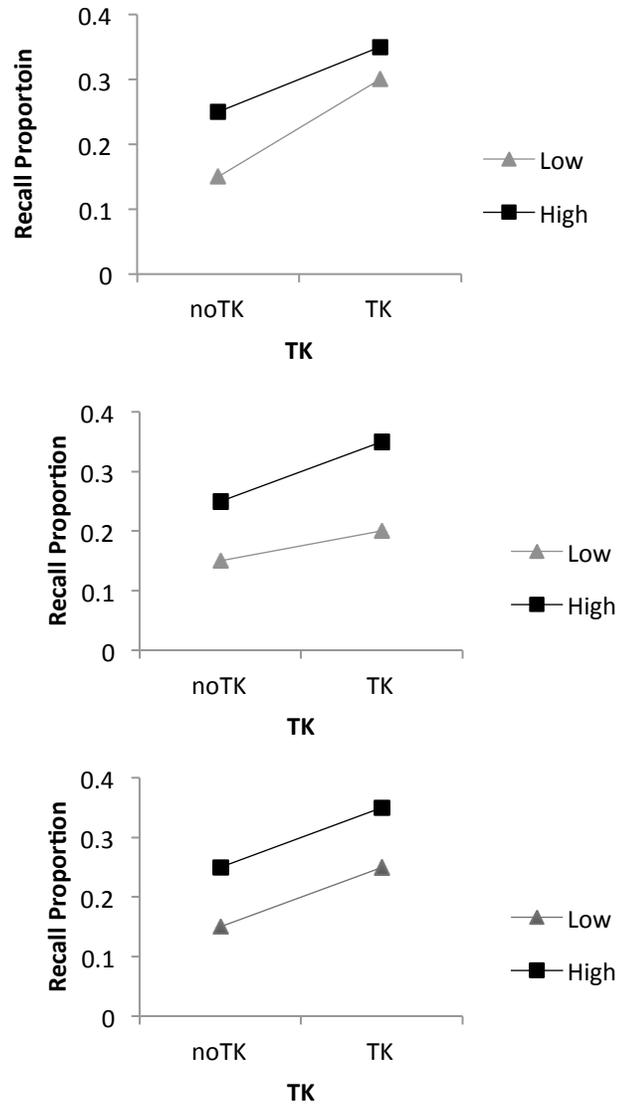


Figure 1. Possible effects of topic knowledge (TK) and skill (e.g. working memory) on recall performance (adapted from Hambrick & Engle, 2002).

Hambrick and Engle (2002) proposed three different models of the relation between TK and WM capacity. As shown in the upper frame of Figure 1 (adapted from Hambrick & Engle, 2002), one possible relation between TK and WM is that TK

compensates for weaknesses in WM, enabling those with less WM to comprehend better. The second frame shows a relationship wherein WM facilitates the use of knowledge such that those with high WM also show the greatest benefit from knowledge. The bottom frame shows a relation wherein high levels of domain knowledge and WM improve memory but operate independently and additively, both contributing to better comprehension.

Hambrick and Engle (2002) evaluated which of these models best describes how TK and WM relate to memory for a radio broadcast of a baseball game (Hambrick & Engle, 2002). Groups of adult participants answered questions about the rules, regulations and terminology of baseball and also self-rated their interest and experience with baseball. WM was measured using a composite of two tasks: an operation span task and a counting span task. Participants then listened to three fictional radio broadcasts of baseball games (lasting about $\frac{1}{2}$ inning each) and answered multiple choice questions regarding each player's turn at bat and answered cloze (fill in the blank) questions on an altered version of the game text.

WM and baseball TK were entered into hierarchical regressions along with age. Results showed both WM and TK independently contributed to memory performance, with TK being a better predictor. There was also a significant interaction between TK and WM that supported the second model shown in Figure 1 wherein the effect of TK on recall of TK-relevant information was greatest for those with higher levels of WM. In other words, TK improved passage memory, but those with low WM capacity benefitted the least, indicating that TK does not compensate for shortcomings in WM (Hambrick &

Engle, 2002). To the contrary, WM played a greater role for those with TK indicating that strong WM may be a necessary component for using TK.

In a follow-up study comparing the effect of WM on recall, Hambrick and Oswald (2005) compared a baseball task to an isomorphic task about a spaceship launch. The purpose of the task comparison was to assess whether WM plays a larger role in a TK-irrelevant task as compared to a TK-relevant task where TK should aid in recall. Participants were required to track the movement of the spaceships/players and subsequently answer questions about the outcome of each at bat (spaceship launch) and report which bases (planets) were occupied, depending on the task. Interestingly, there was a task x WM interaction, suggesting that WM played a larger role in the task requiring participants to draw on their TK. This lends evidence to the hypothesis that using TK requires WM ability. However, there was no WM x TK interaction, indicating that the effect of TK on recall does not vary as a function of WM ability. The lack of interaction in this study is contrary to the results found by Hambrick and Engle (2002). The authors attribute the discrepancy between these two studies to task differences. Namely, they argue that WM and TK are additive for more complex tasks, but assert that this conclusion merits further investigation.

In contrast to the baseball passages used in these studies, the current dissertation employs open-ended recall of academically themed passages that is more representative of typical comprehension and classroom assessments. Furthermore, we explore the joint effects of both word decoding and WM to see if they together contribute to how TK is used for recall. We explore the relation between TK, WM and word decoding for all four passages, across listening and reading modalities. We do this in order to control for the

effects of both predictors similarly across passages. However, word decoding is only relevant to reading passages, so if we find effects of word decoding on passages that do not require reading, they likely reflect other correlated variables, namely general knowledge. We perform these analyses among a large sample of readers with a wide range of abilities as well as among those with specific comprehension deficits (SPCs).

TK and SPCs

SPCs are able to read individual words yet suffer from impairments in higher-level skills that lead to poor comprehension (Cain & Oakhill, 2006). They have been shown to have weaknesses in a number of skills related to comprehension, such as WM (Carretti et al., 2005; Nation et al., 1999; Yuill et al., 1989), which make it more difficult for them to acquire and retain knowledge than skilled comprehenders (Cain et al., 2001; Singer & Ritchot, 1996). It likely also affects their ability to use TK even when they have it. Therefore, another important goal of this dissertation is to investigate how WM ability constrains the benefits of TK in SPCs.

One way to account for the availability of TK is to ensure it is equal between good and poor readers (Cain et al., 2001). Cain et al. (2001) examined inference making and comprehension ability among SPCs and good comprehenders. Children were taught a novel knowledge base about an imaginary planet to ensure that both groups began the study with equivalent TK. Groups were matched on word reading and chronological age and learned the novel knowledge base to criterion. Despite their equal TK for the passage, results indicated that SPCs performed worse than good comprehenders on both elaborative and coherence inferences.

Cain et al. (2001) identified possible sources of poor inferencing, including insufficient memory of the text or knowledge base, as evidenced by SPCs taking longer to acquire the knowledge base and having worse retention after 7 days. But when memory for the knowledge base and text were covaried out, SPCs continued to show inferencing deficits. Thus, even when SPCs have TK and memory for the literal items in a text, they are worse than skilled comprehenders at selecting and integrating the appropriate TK to draw inferences. It is possible that weak WM skills underlie their poorer performance. What is needed to better understand current research findings on the role of TK in comprehension is a study that includes assessments of WM and decoding skill so that the interplay of these factors in comprehension can be better understood. The current study therefore assesses amount of existing TK, as well as WM and decoding skill, to see how they underlie individual differences in comprehension performance, as well as how they explain comprehension deficits in SPCs.

Overview

Aims of the study.

The present study has three aims. We first sought to extend previous research on the effects of TK by studying whether those who score poorly on comprehension measures have less TK to draw from. TK is a strong predictor of comprehension (Alexander, Kulikowich, & Schulze, 1994; Bartlett, 1932; Bransford & Johnson, 1972), but the hypothesis that deficiencies in TK availability correspond to comprehension deficits among poor comprehenders has yet to be investigated. Most studies select knowledge groups based on preexisting expertise on one specific topic (e.g. baseball, chess, physics; Birkmire, 1985; Hambrick & Engle, 2002; Spilich et al., 1979) or train

groups until they have equivalent levels of TK (Cain et al., 2001). Rather than evaluating knowledge for a single topic, the present dissertation assessed participants' existing levels of TK for four passage topics that are less specific to special expertise, and explored whether having TK for these passages facilitated participants' ability to recall them.

A second aim was to investigate whether impairments in WM and word decoding affect participants' ability to use TK. While many readers show improved comprehension when they have TK, the relationship is more nuanced when other abilities are considered (Adams et al., 1995; Cain, et al., 2001; Miller & Keenan, 2009; Recht & Leslie, 1988). There is evidence that TK interacts with reading ability; but it has been shown to have a greater positive effect sometimes for readers with low ability (Miller & Keenan, 2009) and sometimes for readers with high ability (Adams et al., 1995; Hambrick & Engle, 2002). Among SPCs, there is evidence showing persistent deficits in inferencing even when their TK is equivalent to good comprehenders' (Cain et al., 2001), which may be an effect of a failure to retrieve and integrate relevant TK, a process closely tied to WM (Ericsson & Kintsch, 1995; Hambrick & Engle, 2002).

Previous studies examined only 2-way interactions, that is, how the ability to process TK is influenced by one other skill. We extend the results of these studies by investigating three variables (decoding, WM, TK) and their interactions. We use a large sample of children who, as part of a large test battery given by the Colorado Learning Disabilities Research Center (DeFries, et al., 1997; Olson, 2006), are assessed on all these skills as well as a multiple measures of both listening and reading comprehension (Keenan, Betjemann, Wadsworth, DeFries & Olson, 2006). WM was assessed using a composite of a series of span tasks, word decoding was assessed by two word reading

tests, and how TK was assessed will be described below. The battery also assesses nonword reading, which, unlike word decoding, is not influenced by vocabulary knowledge, and is thus better to define our SPC and Control groups, as explained below. We investigated the role of TK in relation to skill strengths and weaknesses in predicting passage recall. Assessing recall is one way to assess the degree to which children organize and understand a passage (Alderson, 2000). In particular, we were interested in whether the relationship between TK and recall is moderated by WM, decoding, and comprehension skill. As a proxy for assessing the reliability of the recall measure, we correlated scores for monozygotic twin pairs as an estimate of low-bound test-retest reliability. These are conservative estimates because while identical twins share genes and family environment, nonshared environmental influences and measurement error may reduce the correlations, $r_{\text{Biddy}}(63) = .34$, $r_{\text{Magellan}}(63) = .66$, $r_{\text{Malcolm X}}(63) = .33$, $r_{\text{Lewis And Clark}} = .40$.

We are particularly interested in examining this relationship in children who are SPCs – defined in this study as showing deficits in listening comprehension (below the 35th percentile) despite relatively strong non-word decoding skills (above the 50th percentile). We define SPCs using non-word decoding because, unlike word decoding, it is not affected by vocabulary (a proxy for general knowledge). Using a word decoding measure would make some children look as though they have decoding deficits when they really just have vocabulary deficits. Using non-word decoding rather than word decoding to define comprehension groups allowed those with poor vocabulary to be kept in the sample. We explored the availability and use of TK across the full distribution of

comprehension skill, as well as between a sample of SPCs and same-age good comprehenders matched for non-word decoding ability.

We compare the effects of WM and word decoding across modalities, though word decoding is only applicable to passages that require reading. Therefore, we anticipate that word decoding ability will constrain the use of TK for reading passages, but not listening passages. This would suggest that word decoding deficits constrain readers' ability to use TK for recall. Alternatively, if we find similar effects of word decoding across listening and reading modalities, this would indicate that word decoding limitations do not influence readers' ability to use TK, even for reading passages that strain their word decoding capabilities. Finding an interaction between word decoding and TK for listening passages would suggest that what some research has identified as a decoding x TK interaction may actually reflect an interaction between TK and other abilities related to decoding that are also necessary for listening passages, namely a correlated variable such as general knowledge.

The effects of TK may depend on how it is assessed. Therefore, a third aim of the current study was to evaluate TK scores as assessed by human raters and then to assess the generalizability of those findings to an assessment of TK using a more objective measure based on a computerized analysis called Latent Semantic Analysis (LSA; Landauer & Dumais, 1997). LSA offers psychometric advantages over traditional subjective scoring (TK-manual) because it is both objective and it quantifies TK across a continuous range from 0 to +1 based on its similarity to the passage. However, because measuring TK using LSA is laborious to transcribe and score, we performed these analyses on a subset of 120 participants. The current study uses transcriptions of oral

responses to an open-ended concept question from each of four passages from the Qualitative Reading Inventory-3 (QRI-3; Leslie & Caldwell, 2001). Results of analyses using TK-LSA scores were compared to analyses using traditional TK-manual scoring in order to evaluate whether LSA is an appropriate measure of TK.

Assessing passage topic knowledge.

While there is little consensus across studies in how best to measure TK (Spyridakis & Wenger, 1991), an important consideration is distinguishing TK from general world knowledge by accurately quantifying what the participant knows about the specific content of the passage. In contrast to general world knowledge, which is general knowledge gained through experience with the world, TK refers to specific, in-depth knowledge about the focal topic of the passage. For example, TK for Ferdinand Magellan would include information about his journey from Spain during which he sailed through the Strait of Magellan and circumnavigated the world. While children who have knowledge of more topics are likely to also have more general knowledge, random effects models including both of these components highlight their distinguishability by demonstrating that children are more likely to correctly answer comprehension questions when they have TK for the passage even when their general knowledge is controlled (Compton, Miller, Gilbert, & Steacy, 2013). The present study assesses the similarity between general knowledge, as measured by the vocabulary subtest of the Wechsler Intelligence Scale (Wechsler, 1974; Wechsler, 1981; Wechsler, 1991; Wechsler, 1997), and TK to see how participants perform on passages for which they do and do not have specific knowledge after accounting for general knowledge. We measure the unique contributions of TK beyond the effects of general knowledge by entering each variable as

a separate step in a regression model. This allows us to determine whether comprehension varies across passages as a function of children's varying TK.

TK is assessed by a single open-ended question provided with the passages in the Qualitative Reading Inventory-3 (QRI; Leslie & Caldwell, 2001). Before encountering each passage, participants learn that they will be asked a question to see how much they already know about the topic. The open-ended format gives readers the liberty to convey what they already know without directly querying information contained in the passage as a long list of direct questions might do. As described in the QRI-3 manual (Leslie & Caldwell, 2001), raters assign a discrete TK score (0, 1 or 2) based on the participant's answer to the concept question. After responding to the concept question, participants either read or listen to a story, and then retell what they remember from the passage and answer 6 open-ended comprehension questions.

Subjective TK scoring based on the test manual (TK-manual) has some limitations. Though a participant who receives a score of 2 has more TK than one who receives a 1, two answers that receive a maximum score of 2 may differ in their content. Another concern with TK manual is that it is discrete and accounts for limited variability in responses. The difficulty is that we assess the relation between TK-manual and recall scores, which are continuous. For this reason, we have supplemented our analysis using TK-manual with another measure, TK-LSA, as described below. Lastly, though questions are designed to tap into TK that is relevant for comprehending the associated passage, the TK-manual scoring paradigm does not directly assess the relationship between TK and the content of the passage, though the importance of this consideration is not unique to this method (Tobias, 1994).

Despite these concerns, extant literature has successfully used an open-ended concept question to measure TK (Compton et al., 2013; Miller & Keenan, 2009; Priebe et al., 2012). However, in order to assess the generalizability of our findings using raters' judgments of TK on concept questions, the present study proposes to supplement TK-manual scoring with a second scoring method known as Latent Semantic Analysis (LSA; Landauer & Dumais, 1997). LSA is an automated program that employs a mathematical matrix decomposition technique (singular value decomposition) to extract and infer relations between texts based on the actual contextual usage of the component words (for details, see Landauer & Dumais, 1997; Landauer, Foltz, & Laham, 1998). LSA assigns scores based on information about all the contexts in which a given word (or set of words) does and does not occur (Landauer, 2002) and can represent entire passages as vectors in multidimensional "semantic space." Passages can then be judged against each other by their proximity in semantic space (represented by cosine values) that range continuously from 0 to 1. In our case, LSA assesses the semantic similarity between what the child says in response to the concept question and the passage text.

LSA offers two potential advantages over traditional subjective TK-manual scoring: greater objectivity, and a wider range of possible TK scores (potentially a more sensitive measure). Though TK has not been used in the context of scoring TK before, comparisons between subjective scoring of passage retellings using an idea checklist (recall-checklist) and LSA scoring of recalls (as compared to the original text; recall-LSA) have produced moderately high correlations ($r(48) = .6-.7$), validating LSA as an assessment of text similarity (Fazendeiro, Keenan, & Betjemann, 2002; Mao, Meenan, Hua, & Keenan, 2012). LSA scores have been evaluated based on the comparison of an

average retelling of the text vs. the actual passage as a comparison document, and an average retelling of a text vs. an expert's retelling as the comparison document, which mainly consists of essential idea units. Both forms of comparison document produce similar average LSA scores ($M_{\text{original}} = .706$ vs. $M_{\text{expert}} = .712$) lending some support to the suggestion that LSA is capable of differentiating essential ideas as human scorers do (Mao et al., 2012).

Chapter Two: Method

Participants

The sample consists of 509 participants in Grade 7 and above who completed Level 7 of the QRI-3 (Leslie & Caldwell, 2001) selected from a large sample of twins and their siblings recruited for a behavioral genetic study of comprehension skills (Keenan et al., 2006) as part of the Colorado Learning Disabilities Research Center (Olson, 2006). The median age was 14.67 years ($SD = 1.87$). This group of participants was selected because Level 7 passages tend to show variability in TK. Subgroups of SPCs ($n = 60$) and controls ($n = 60$) were selected from this sample to explore group differences in cognitive abilities and the interaction between comprehension group and TK (Table 7).

Measures

Qualitative Reading Inventory-3 (QRI-3; Leslie & Caldwell, 2001). The QRI-3 is used as both a TK measure and an outcome measure. The entire test is composed of several grade-appropriate passages. Level 7 includes four passages, two of which were read aloud and two of which were listened to from a tape. They included passages about Malcolm X and Lewis and Clark (reading), and Bidy Mason and Ferdinand Magellan (listening).

The QRI-3 evaluates comprehension using open-ended recalls. Recall proportion scores are assigned by tallying the number of passage-based idea units that the reader

produces during recall out of the total number of idea units. Idea unit checklists are provided by the QRI-3 manual and include most of the ideas contained in the corresponding passage. Cronbach's alpha shows excellent reliability for this measure across raters ($\alpha > .94$).

Topic knowledge (TK).

Concept question scores based on the QRI-3 manual (TK-manual). Before each passage, participants answer an open-ended concept question to see how much they already know about the topic. The concept questions correspond to the topic and are: "What is slavery," "Who was Malcolm X," "Who was Ferdinand Magellan," and "Who were Lewis and Clark." Human raters in the Reading and Language Lab assigned scores to responses to the concept question for each passage on the QRI-3 (Leslie & Caldwell, 2001) using the method described in the test manual (TK-manual). Scores are 0 (no knowledge), 1 (some knowledge), or 2 (extensive knowledge) depending on the quality of the answer to the concept question. Cronbach's alphas between two raters were good, with an average of .81 across passages.

Latent Semantic Analysis (TK-LSA). LSA (Landauer & Dumais, 1997) is used as a secondary measure of TK (TK-LSA). Answers to the concept questions for each of the four Level 7 passages of the QRI were transcribed for the sample of SPCs and controls and entered into the LSA website (<http://lsa.colorado.edu>) using a document-to-document comparison in the semantic space defined by a corpus of general readings ranging in difficulty up to 12th Grade (Laham, Jones, Stahl &, DePaula, 1998). The output consisted of the cosine of the angle between the vectors representing the text and the child's answer

to the concept question in semantic space. A score of 0 indicates dissimilarity and a score close to 1 indicates similarity. When a child indicated that they had no TK of a passage, it was manually coded as a 0 and not entered into the LSA algorithm. Transcribed concept question responses were compared to the corresponding original passage.

Group selection measures.

The present study investigates the full sample of children across the comprehension spectrum, but also performs analyses comparing SPCs to a sample matched for non-word decoding. SPCs were those scoring at or below the 35th percentile on the listening comprehension composite ($z \leq -.22$) and at or above the 50th percentile on non-word decoding ($z \geq .15$). Same-age controls were selected because they scored at or above the 50th percentile for both non-word decoding and listening comprehension ($z \geq .14$) and were matched with SPCs for non-word decoding.

Listening comprehension composite. This composite is derived from the standardized average of the separately standardized *KNOW-IT Test* (Barnes & Dennis, 1996; Barnes, Dennis, & Haefele-Kalvaitis, 1996) and the Woodcock Johnson Test of Oral Comprehension-III (Woodcock, McGrew, Mather, 2001).

KNOW-IT test. Participants learned to criteria a novel knowledge base relevant to the passage topic. They then listened to a long story about a fictional planet called Gan. Upon finishing the story, they answered several questions assessing their literal and inferential comprehension. Scores to comprehension questions were assigned as follows: 3 points for a full response without prompting, 2 points for a full response after the

prompt “tell me more about that,” 1 point for a partial response that was not improved when prompted, and 0 points for incorrect answers and “don’t knows.”

Woodcock-Johnson Test of Oral Comprehension (WJOC). Children listen to a series of short (1-2 sentences) passages and fill in the missing word for each.

Cognitive variables.

Non-word decoding. This is the standardized composite of accuracy and latency scores for two tests of non-word reading developed by Olson, Forsberg, Wise and Rack (1994). One assessed reading of 45 one-syllable non-words (e.g., ter, strale), while the other assessed reading of 40 two-syllable non-words (e.g., vogger, strempick).

Word decoding. Word decoding skill was measured with two word reading tests, the Timed Oral Reading of Single Words (Olson et al., 1994) and the Peabody Individual Achievement Test (PIAT) word recognition subtest (Dunn & Markwardt, 1970).

Working memory (WM). WM was measured using a composite of sentence span (Daneman & Carpenter, 1980), counting span (Case, Kurland, & Goldberg, 1982), and forward and backward digit span from the WISC-R (Wechsler, 1974) or the WAIS-R (Wechsler, 1981).

Vocabulary. General knowledge was measured using the vocabulary subtest of the Wechsler Intelligence Scale for Children-Revised/Wechsler Adult Intelligence Scale-Revised/Wechsler Intelligence Scale for Children-3rd. ed./Wechsler Adult Intelligence Scale-3rd ed. (WISC-R/WAIS-R/WISC-III/WAIS-III; Wechsler, 1974; Wechsler, 1981; Wechsler, 1991; Wechsler, 1997).

Chapter Three: Results

Is Knowledge Related to Recall?

We expected higher TK to relate to higher general knowledge, recall and other abilities. We performed correlations on these variables using the TK-manual measure. Table 1 presents correlations across the full sample of 509 participants between TK-manual for each QRI-3 (Leslie & Caldwell, 2001) passage and general knowledge, WM, word decoding, and recall scores.

Table 1

Correlations between Predictors and Recall Proportion for the Entire Sample (N = 509)

	GK	WM	Word dec.	Recall			
				Biddy	Magellan	Malcolm X-Read	Lewis & Clark- Read
TK-manual							
Biddy	.12* ^a	0.01	.11*	.17** ^f			
Magellan	.43** ^a	.23**	.42**		.33** ^d		
Malcolm X	.36** ^c	.13** ^b	.27** ^b			.17** ^g	
Lewis & Clark	.49** ^c	.28** ^b	.44** ^b				.26** ^g
GK		.41** ^a	.67** ^a	.29** ^g	.52** ^c	.29** ^f	.36** ^g
Word decoding		.54**		.20** ^f	.41** ^d	.19** ^c	.27** ^c

Note. GK = general knowledge, ** $p < .01$, * $p < .05$. ^a = 508 ^b = 507 ^c = 506 ^d = 504 ^e = 503 ^f = 502 ^g = 501

As we hypothesized, less TK is related to poorer recall, indicating that TK deficits may be one factor underlying poor recall. As expected, TK is also significantly positively correlated with WM and word decoding for all passages except Biddy Mason, which highlights the need to distinguish cognitive abilities from TK in predicting recall, as well as to investigate how they influence each other. Word decoding is also positively

correlated with recall, and not more so for reading than listening passages. This likely reflects the close relationship between word decoding and other variables, including general knowledge ($r(506) = .67$), which contribute to the construction of a situation model.

We see modest to moderate positive correlations between TK-manual and general knowledge, indicating a need to take general knowledge into account when interpreting the effects of TK. The modest correlations for two passages are likely a product of the low variability in TK scores for those passages, with the majority of participants having TK for Bidy Mason (“what is slavery?”) and few having TK for Malcolm X (“who was Malcolm X?”). One reason for the stronger correlation between general knowledge and recall than between TK and recall is because of the continuous nature of the general knowledge measure as compared to the discrete TK-manual measure. The relatively weaker strength of the correlations between TK-manual and recall also indicates that there is not perfect consistency between those with a high score on TK-manual and who is getting a high score on recall, suggesting that participants are not merely recalling knowledge they had before encountering the passage.

We next assessed whether TK predicts recall above and beyond general knowledge. When we compare the contribution of TK and general knowledge to recall, we find that for three of the four passages TK predicts recall even after accounting for general knowledge (Table 2). This indicates that there is a unique contribution of TK that goes beyond what is offered with general knowledge.

Table 2

Linear Regression with General Knowledge and TK Predicting Passage Recall

Step	Predictor	Biddy			Magellan			Malcolm X-Read			Lewis & Clark-Read		
		R ²	ΔR ²	β	R ²	ΔR ²	β	R ²	ΔR ²	β	R ²	ΔR ²	β
1	GK	.08	.08***	.03***	.27	.27***	.07***	.09	.09***	.30***	.13	.13** *	.04***
2	TK-manual	.10	.02**	.03**	.28	.02**	.02**	.09	.00	.01	.14	.01*	.17*

Note. GK = general knowledge, *** $p < .001$, ** $p < .01$, * $p < .05$

Do Cognitive Skills Constrain the Effect of TK on Recall?

We employed a regression strategy similar to that used by Hambrick and Engle (2002) to evaluate whether TK-manual and WM, and TK-manual and word decoding interact to predict recall. We had expected WM to constrain the effect of TK on recall across all passages, but anticipated word decoding would only constrain the effect of TK for reading passages. In order to compare the effects of TK across passages of different modalities, we entered both WM and word decoding as predictors for all four passages. We controlled for WM and word decoding ability in a series of 6-step hierarchical regressions for each passage to investigate how TK-manual contributes to recall beyond these variables, as well as to see whether they moderate the effect of TK (Table 3). Centered variables for WM and word decoding were entered in the first step to evaluate their unique effects on recall performance. A centered variable for corresponding passage TK-manual was entered in Step 2 to evaluate whether it predicted additional variance in recall performance. Steps 3, 4, and 5 included cross-product terms representing WM x word decoding, WM x TK, and TK x word decoding interactions. Lastly, Step 6 included the three-way interaction between WM x TK x word decoding.

Table 3

Hierarchical Regressions using the Full Sample (n = 509) Predicting Recall Proportion

Step	Predictor	Biddy			Magellan			Malcolm X -Read			Lewis & Clark -Read		
		R ²	ΔR ²	β	R ²	ΔR ²	β	R ²	ΔR ²	β	R ²	ΔR ²	β
1	Decoding & WM	.05	.05***		.17	.17***		.06	.06***		.07	.07***	
2	TK-manual	.08	.02***	.15***	.21	.03***	.19***	.08	.02***	.13***	.10	.02***	.17***
3	WM x Decoding	.08	.01	-.08	.21	.00	.00	.08	.00	-.07	.10	.00	-.03
4	TK-manual x Decoding	.08	.00	-.06	.21	.00	-.06	.09	.01	.08	.10	.00	.01
5	TK-manual x Decoding x WM	.08	.00	.02	.21	.00	-.04	.09	.00	-.01	.10	.00	.01
6	TK-manual x Decoding	.09	.00	-.06	.21	.00	-.06	.09	.00	.01	.10	.00	.00

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

As shown in Table 3, TK-manual predicts comprehension even after accounting for WM and word decoding across all passages. Again, we controlled for both WM and word decoding for all passages to allow us to compare the effects of TK consistently across passages, and because word decoding is closely related to other relevant comprehension components, e.g. general knowledge. Because WM and word decoding were controlled in Step 1, these results underscore the importance of TK and provide additional evidence for the notion that TK facilitates recall. The introduction of two- and three-way interaction terms in Steps 3, 4, 5 and 6 did not contribute significant additional variance to the model for any of the passages, indicating that the influence of TK-manual on recall does not vary as a factor of either WM or word decoding. Thus, across the full

distribution of participants, WM and word decoding do not appear to constrain how TK affects passage recall.

Are Manual and Automated Methods of Scoring a Concept Question Related?

Because TK-manual is a discrete measure (0, 1, 2), we next explored the possibility that the interactions in the above models did not reach significance because TK-manual may not be a sufficiently sensitive measure of knowledge. We tested this hypothesis first by investigating the correlations between TK-manual and TK-LSA (as scored by an automated measure, LSA). Then we compared results from the above regressions, which employed TK-manual as a predictor, to the same regressions in a subsample of participants ($n = 120$) using TK-LSA as a predictor. Because TK-LSA is time-consuming to score, we were only able to do this for the sample of participants who were also used for the analyses comparing SPCs and controls.

Correlations between TK-LSA and TK-manual range from modest to high (Table 4). We had expected TK-LSA and TK-manual to be similar, with TK-LSA being a better predictor. The correlation between both measures of TK and recall were comparable for two of the four passages (Magellan and Lewis & Clark). The other two passages show differences across methods for two reasons: 1.) As mentioned previously, there is little variability in knowledge for the Bidy Mason passage and the Malcolm X passage when manually scored; and 2.) Neither of the concept questions for these two passages is closely related to the content of the passage. The concept question for Bidy Mason asks, “What is slavery” whereas the passage discusses one slave’s walk across the country with her master and the actions she takes to gain freedom. The concept question for Malcolm

X asks “who was Malcolm X” while the passage discusses him teaching himself to read in prison. The correlation between TK-LSA and recall is lower for Malcolm X, likely because the associated concept question bears little relationship to the passage content. When raters score TK-manual for this question, readers who know more about Malcolm X’s life as a civil rights activist are likely to score higher. When scored using TK-LSA, however, answers relating to Malcolm X’s activism are unlikely to score high because this TK bears little relationship to the passage content against which responses are compared. Overall, the correlations between TK-LSA and recall is higher than the correlations between TK-manual and recall, likely because TK-LSA assesses knowledge that is directly related to passage content and therefore more likely to aid in recall, but also because it is a continuous measure as opposed to the restricted range of TK-manual.

Table 4

Correlations between TK-manual, TK-LSA, and Recall Checklist Scores

Knowledge		TK-LSA (n=120)	Recall Checklist (n=120)
TK-manual (n=120)	Biddy	.39**	.09 ^a **
	Magellan	.86**	.40**
	Malcolm X	.54**	.24 ^a **
	Lewis & Clark	.65**	.23**
TK-LSA (n=120)	Biddy		.25 ^a **
	Magellan		.41**
	Malcolm X		.14 ^a
	Lewis & Clark		.26**

Note. ^a n = 119, **p < .01, *p < .05

Do Results from Measuring TK Generalize to an Automated Method?

We next investigated whether we would find a similar influence of TK-LSA on recall as we did for TK-manual in the first set of hierarchical regressions. As shown in Table 5, using TK-LSA for the matched subsample explains unique variance in recall after accounting for word decoding and WM for three of the four passages: Bidly Mason, Ferdinand Magellan, and Lewis and Clark. Unlike TK-manual, TK-LSA does not explain variance on Malcolm X, which may be due to the difference in the concept questions associated with each passage, as described above.

Table 5

Hierarchical Regressions using Matched Sample Predicting Recall Proportion

Step	Predictor	Bidly			Magellan			Malcolm X -Read			Lewis & Clark - Read		
		R ²	ΔR ²	β	R ²	ΔR ²	β	R ²	ΔR ²	β	R ²	ΔR ²	β
1	Decoding & WM	.14	.14***		.23	.23***		.11	.11**		.07	.07*	
2	TK-LSA	.19	.06**	.24**	.26	.05**	.26**	.12	.01	.10	.10	.03*	.20*
3	WM x Decoding	.19	.00	-.02	.26	.01	.11	.12	.00	-.06	.10	.00	.05
4	WM x TK-LSA	.22	.03~	.17~	.27	.01	-.13	.12	.00	.08	.10	.00	-.03
5	TK-LSA x Decoding	.23	.01	-.20	.29	.03*	.26*	.12	.00	.02	.10	.00	-.02
6	WM x TK-LSA x Decoding	.23	.00	-.04	.29	.00	.10	.13	.00	.13	.11	.01	.13

Note. *** $p < .001$, ** $p < .01$, * $p < .05$, ~ $p = .05$

The most important difference between the regressions employing TK-LSA as a predictor, as opposed to TK-manual, is that two of the 2-way interactions with TK are significant or nearly significant. First, for Bidly Mason, there is a trend toward an interaction between TK-LSA and WM ($p = .05$) suggesting that as WM increases by 1-point, the effect of TK-LSA on recall increases by .17 recall idea units. Therefore, those

with higher WM benefit more from TK-LSA on the Bidy Mason passage and, conversely, as TK-LSA increases, WM has a greater impact on recall. Secondly, on the Magellan passage, the interaction between TK-LSA and word decoding is significant. As word decoding increases by one unit, the effect of TK-LSA increases by .26 recall idea units. This finding is difficult to interpret because Ferdinand Magellan is a listening passage, but this interaction must reflect other skills related to word decoding, such as general knowledge. This is further supported by our results, which show that general knowledge explains the most variance in recall for Ferdinand Magellan (Table 1) as compared to the other passages. In sum, these two small interactions are evidence that TK-LSA is sensitive to somewhat different knowledge than TK-manual, though TK-LSA did not pick up on the effects of knowledge on Malcolm X the way TK-manual did.

An additional series of regressions helped to determine whether TK-LSA is a stronger recall predictor than TK-manual. If TK-LSA is a more sensitive measure than TK-manual, it should explain additional variance in recall after accounting for TK-manual. Table 6 presents the results of regressions including TK-manual as Step 1 and TK-LSA as Step 2 in predicting recall. For these regressions we again use the subsample for which all participants have scores for both TK-manual and TK-LSA ($n = 120$).

Table 6

Hierarchical Regressions Comparing TK-manual and TK-LSA for Predicting Recall

Step	Predictor	Biddy Mason			Magellan			Malcolm X- Read			Lewis and Clark-Read		
		R ²	ΔR ²	β	R ²	ΔR ²	β	R ²	ΔR ²	β	R ²	ΔR ²	β
1	TK-manual	.01	.01	.09	.16	.16**	.40	.06	.06**	.24	.05	.05*	.23
2	TK-LSA	.06	.05*	.25	.17	.02	.25	.04	.00	.01	.08	.02	.20

Note. **p<.01, *p<.05

Results show that TK-LSA does not explain variance beyond TK-manual, except for Bidy Mason. TK-LSA may be more sensitive for Bidy Mason because there is little variability in TK-manual for this passage. TK-LSA is very similar to TK-manual and while it may pick up on slightly different knowledge for some passages, it is not a significantly better predictor of recall, particularly for a passage such as Malcolm X.

On Which Skills do Controls and SPCs Differ?

Table 7 presents means, standard deviations and results of paired t-tests comparing SPCs and controls on age, standardized versions of non-word decoding, WM, listening comprehension, TK-manual, general knowledge (vocabulary) and recall scores. Cognitive variables were standardized by regressing raw scores on age and age squared and saving the standardized residuals. To determine whether a primary deficit in SPC is related to limitations in topic knowledge, we compared TK-manual between comprehension groups. The SPC group shows significant deficits on TK-manual for three of four passages (Malcolm X, Ferdinand Magellan, and Lewis and Clark). There are no TK differences on Bidy Mason, likely because there is little variability in knowledge for this passage, with 98% of children demonstrating at least some TK about the topic of slavery. This finding suggests that a TK deficit may be a contributor to poor comprehension, though it is not the only component. SPCs also show deficits relative to controls not only on listening comprehension (the variable on which they were selected) but also on word decoding, WM, and WISC vocabulary (general knowledge).

Table 7

Paired t-test Comparisons for SPCs and Controls on Participant Characteristics, Cognitive Abilities, TK-manual, and Recall

Variable	$M_{\text{Controls}} (SD)$ (n=60)	$M_{\text{SPC}} (SD)$ (n=60)	t
Age (years)	14.98 (1.5)	15.14 (1.9)	-.54
zNonword	.39 (.14)	.39 (.14)	.14
zListeningComp Composite	.76 (.43)	-.96 (.62)	16.08**
zWM	.61 (.93)	.10 (.92)	3.07**
zWordRec	.81 (.53)	.32 (.61)	4.44**
WISC vocabulary subtest	.61 (.89)	-.28 (.94)	5.41***
TK-manual total all passages	4.57 (1.60)	3.53 (1.72)	3.50**
Bidly	1.27 (.46)	1.25 (.54)	.18
Magellan	.93 (.82)	.58 (.67)	2.36*
Malcolm X	.73 (.78)	.40 (.64)	2.53*
Lewis and Clark	1.63 (.52)	1.30 (.74)	2.72**
TK-LSA			
Bidly	.26 (.10)	.27 (.11)	-.392
Magellan	.28 (.22)	.18 (.19)	2.31*
Malcolm X	.12 (.12)	.08 (.11)	1.83
Lewis and Clark	.38 (.13)	.32 (.13)	2.46*
Recall-proportion-total all passages	1.15 (.36)	.82 (.30)	5.25**
Bidly Mason	.31 (.12)	.24 (.10)	3.19**
Magellan	.34 (.12)	.22 (.11)	5.42**
Malcolm X-Read	.20 (.09)	.14 (.07)	4.37**
Lewis & Clark-Read	.30 (.10)	.23(.10)	4.34**

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

Do SPCs' Skill Weaknesses Limit the Effect of TK on Recall?

To disentangle the contribution of deficits in TK, word decoding, and WM to recall among controls and SPCs, the next series of analyses consider how TK interacts with WM and word decoding among the matched sample of SPCs and controls. In a series of regressions, WM and TK-manual were entered as Step 1, followed by their interaction in Step 2 (Table 8). In a second series, word decoding and TK-manual were entered as Step 1, followed by their interaction in Step 2 (Table 9). These analyses corroborate previous findings with the full sample indicating that no interactions reach

significance for any passage. This confirms that TK-manual has an equivalent effect for the sample of SPCs and controls regardless of WM or word decoding skill (refer to the third frame in Fig. 1).

Table 8

Hierarchical Regressions for Matched Sample with WM (n = 120)

Step	Predictor	Biddy			Magellan			Malcolm X-Read			Lewis & Clark-Read		
		R ²	ΔR ²	β	R ²	ΔR ²	β	R ²	ΔR ²	β	R ²	ΔR ²	β
1		.13	.13***		.24	.24***		.15	.15***		.08	.08**	
	WM			.35***			.30***			.31**			.17
	TK-manual			.07			.35***			.21*			.19*
2		.14	.00		.25	.00		.39	.00		.08	.00	
	TK-manual x WM			-.06			-.05			.01			-.03

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

Table 9

Hierarchical Regressions for Matched Sample with Word Decoding (n = 120)

Step	Predictor	Biddy			Magellan			Malcolm X -Read			Lewis & Clark - Read		
		R ²	ΔR ²	β	R ²	ΔR ²	β	R ²	ΔR ²	β	R ²	ΔR ²	β
1		.05	.05*		.23***	.23***		.06	.06*		.07	.07*	
	Decoding			.21*			.30**			.06			.14
	TK-manual			.09			.25*			.23*			.18
2		.06	.01		.23	.01		.07	.00		.07	.00	
	TK-manual x decoding			-.13			.15			-.10			-.01

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

Because of the numerous skill weaknesses among SPCs, we asked whether there are differences beyond WM and word decoding that affect how TK relates to recall for each group. To do this, we examined whether comprehension group (SPC vs. control) interacts with TK. TK-manual and comprehension group were Step 1 and their

interaction was Step 2 in a hierarchical regression for each passage. For none of the passages do we see an interaction between TK-manual and comprehension group, indicating that TK-manual has the same effect on recall for both comprehension groups.

The finding that SPCs and controls both recall more when they have topic knowledge can be seen in the mean recall proportion for each group (Table 10). The Malcolm X and Magellan passages were selected for further analysis because there are an adequate number of participants from each group with and without TK. The results of an ANOVA on the data from these two passages showed that for both passages there was a main effect of group ($F_{\text{Malcolm X}}(1, 113) = 7.10, p < .01$; $F_{\text{Magellan}}(1, 114) = 24.00, p < .001$) and a main effect of TK ($F_{\text{Malcolm X}}(2, 113) = 3.52, p = .03$; $F_{\text{Magellan}}(2, 114) = 5.53, p < .01$). However, there was no interaction between group and TK for either passage, $F_{\text{Malcolm X}}(2, 113) = .30, p = \text{ns}$; $F_{\text{Magellan}}(2, 114) = .92, p = \text{ns}$. These results suggest that despite deficits in word decoding and WM among SPCs, improvement in recall due to TK is equivalent to that seen among controls.

Table 10

Mean Recall Proportion for SPCs and Matched Controls with and without TK-manual for Each Passage

Passage	No TK-manual	TK-manual	Change in recall proportion
Biddy Mason			
Controls	-- ($n = 0$)	.31(.12) ($n = 60$)	
SPCs	.11(.08) ($n = 3$)	.24(.10) ($n = 56$)	+.13
Magellan			
Controls	.30(.11) ($n = 22$)	.37(.12) ($n = 38$)	+.07
SPCs	.18(.09) ($n = 31$)	.26(.11) ($n = 29$)	+.08
Malcolm X			
Controls	.17(.07) ($n = 28$)	.22(.10) ($n = 32$)	+.05
SPCs	.13(.07) ($n = 41$)	.16(.08) ($n = 18$)	+.03
Lewis and Clark			
Controls	.42(--) ($n = 1$)	.30(.10) ($n = 59$)	-.12
SPCs	.17(.09) ($n = 10$)	.23(.10) ($n = 50$)	+.06

Chapter Four: Discussion

The Effect of TK on Comprehension

In contrast to many studies of poor comprehension, which focus primarily on specific skill weaknesses, the present research investigated TK as a contributor to comprehension and comprehension deficits. Substantial research finds that having TK provides a framework for interpreting texts, allowing readers to make connections between ideas and drawing inferences that ultimately lead to better understanding. We hypothesized, then, that a potential source of poor comprehension would be having less TK. We found evidence for this relationship between TK and recall, highlighting the role of TK in accurate comprehension and also indicating that having less TK may be one source of poor comprehension.

There are also differences in how TK and general knowledge relate to recall. As we expected, having TK is related to having more general knowledge, but the two represent slightly different knowledge components, with TK generally explaining more variance in recall. The one passage for which TK does not explain additional variance is Malcolm X, a passage for which most children have no TK. Our findings regarding the importance of TK above general knowledge are consistent with Hambrick and Engle (2002) who, using structural equation modeling, found distinct effects of baseball TK on memory performance independent of general knowledge (as measured using vocabulary and responses to a cultural knowledge measure). Beyond comprehension, it is also

aligned with the finding that TK increases fluency among poor decoders (Priebe et al., 2012), even though their general knowledge remains the same.

This distinction between TK and general knowledge is also consistent with Compton et al. (2013), whose primary focus was to explore a relatively new methodology for identifying effects of person level characteristics (e.g. general knowledge), textual characteristics (e.g. listening vs. reading), and their interaction in a single model. Similar to the current study, Compton and colleagues assessed TK with a concept question from the QRI-3 (Leslie & Caldwell, 2001), but participants were in 5th grade and therefore the passages and concept questions were different from those used in the current study. Furthermore, Compton et al. measured general knowledge with the Academic Knowledge subtest of the Woodcock-Johnson—Third edition (Woodcock et al., 2001) and comprehension using QRI-3 questions rather than recall. Similar to our results, Compton et al. found that having passage-specific TK corresponded to higher scores on QRI-3 comprehension questions even after controlling for general knowledge, and general knowledge was not significant after controlling for passage-specific TK. Compton and colleagues' results, taken together with those of the present study, suggest that TK is important for comprehension beyond general knowledge across methodologies, participant ages, and several passage topics. Additionally, the results of the current study validate the use of Compton and colleagues' relatively new item response random effects modeling technique as a method for determining the contribution of participant characteristics, textual characteristics, and their interaction to comprehension.

Collectively, these findings mean that even if studies account for general knowledge, a child's comprehension may vary across passages as a result of varying levels of specific TK for each topic. When children have less TK, their comprehension suffers. Neither our study nor previous studies experimentally manipulated participants' levels of TK, so we cannot make any claims of causality, but we did investigate several passages for which children differ in TK. Therefore, the present findings provide evidence for the notion that a lack of TK may lead to poorer comprehension even for a good comprehender, and offer a strong rationale for including TK in comprehension assessments.

The Relationship between TK and other Comprehension Components

The relationship between component comprehension skills has made it difficult for studies to identify whether poor comprehension arises from poor skills, a lack of applicable TK, or a combination of both. Research has rarely observed how these factors operate together, leaving it unclear whether findings regarding TK are actually due to TK or to correlated comprehension abilities. We confirm the positive relationship between WM, word decoding, and TK, which supports previous work suggesting that readers with stronger abilities are better able to accumulate knowledge (Cain et al., 2001; Singer & Ritchot, 1996). This finding also indicates a need to disentangle the effect of TK from other comprehension skills.

TK has been long identified as a contributor to comprehension, but it was not always clear whether it contributed beyond the effects of more general skills such as WM and word decoding. Previous research has also produced differing results about the

relative contributions of TK and WM to comprehension (Hambrick & Engle, 2002). For example, some studies have found that TK has a direct effect on comprehension whereas WM does not (Britton et al., 1998), while others have found effects of both (Haenggi & Perfetti, 1992, 1994). Discrepancies are likely due to differences across measures of WM, with some studies using a single span task and others using tasks that may tap WM as well as reading ability. The present study used a composite of four WM span measures and found that WM does predict recall, and that TK plays a unique role that goes beyond both WM and word decoding skills.

Given the potential importance of increasing TK as a mode of improving comprehension, the present study sought to investigate whether weaknesses in other skills, namely WM and word decoding, place limits on participants' abilities to use TK for recall. In other words, did having TK only produce better recall for those participants with stronger WM and/or word decoding abilities? Overall, there was little evidence to suggest that WM or word decoding ability limit children's abilities to use TK; children across the skill spectrum benefitted similarly when they had TK. This is in contrast to some previous work, which found that those with greater WM capacity (Hambrick & Engle, 2002) and reading ability (Adams et al., 1995) were better able to use TK. Yet the current results are consistent with Miller and Keenan (2009), who found that poor decoders were able to use TK to reduce their deficits in recall of central information. Though Miller and Keenan found an effect of TK on recall of central information only for poor decoders, our results are similar in that in both studies, poor decoding abilities did not constrain participants' ability to benefit from TK. The current results also align

with research by Recht and Leslie (1988) who, though there was a low cutoff for the “high comprehension” group (above the 30th percentile), found no interaction between TK and comprehension ability. In their study, both high and low comprehension groups’ memory improved similarly from TK. This is positive news for interventionists looking to ameliorate poor comprehension because TK is related to better comprehension for those with either strong or weak component skills. Additional research should test whether interventions focused on increasing TK produces improved comprehension for subgroups of children.

Generalizing Results to TK-LSA

Given the discrepancies in previous research, which use several different measures of TK, we tested whether our finding would generalize to an automated measure of knowledge. We had anticipated TK-LSA to be more sensitive because of its continuous nature (as opposed to the restricted range of the TK-manual measure), and thus to show a stronger relationship with recall. While TK-LSA picked up on a small interaction that TK-manual did not find, there were notable similarities between the two knowledge measures. Rather than TK-LSA being more sensitive, the two measures are closely correlated and explain similar variance in recall.

An effect found by using TK-LSA that TK-manual did not find was that those with stronger WM derive more benefit from TK for the Bidy Mason passage. This finding supports a previous small interaction supporting the “rich get richer” model for TK and WM, where those with greater WM ability also benefitted more from TK (Hambrick & Engle, 2002). It also echoes the interaction between WM and task type

found by Hambrick and Oswald (2005), wherein WM had a greater predictive effect for the task that was designed to tap TK. Most research has failed to investigate interactions between TK and cognitive variables, but the interactions that have been reported tend to be marginal or non-significant and our results follow this pattern. The current results support tentative findings that good WM is important for using TK but also suggest that some of the discrepancies in previous studies are due to differences in how comprehension, WM, and knowledge are measured. Specifically, studies allowing for a more continuous assessment of TK (Hambrick & Engle, 2002, rated baseball knowledge on a 5 point scale; Adams et al., 1995, rated football knowledge on a 22 point scale) may be more likely to find effects of ability on the use of TK, but this conclusion bears replication. By and large, the current results validate a discrete TK-manual system for scoring TK, indicating that scoring TK by hand is equally sensitive to automated measures.

The Effect of TK on Recall for SPCs

We were particularly interested in investigating whether WM and word decoding impairments would limit SPCs' abilities to draw from TK. SPCs are known to have deficits in WM and word decoding ability (which is highly influenced by general knowledge), which was confirmed in this study, but interestingly they also displayed less TK than their same-age peers matched for non-word decoding ability. This lends support to the hypothesis that SPCs' comprehension deficits stem from weaknesses in higher-order skills, including TK.

We directly tested the hypothesis that deficits among SPCs arise from higher-order deficits by assessing whether SPCs are less able to make use of TK than their peers matched for non-word decoding ability because of other cognitive weaknesses. While we did discover that SPCs had less TK available than their peers, we found that they were equally able to use TK to benefit comprehension when they had it. Because SPCs are able to use TK when they have it, this leads us to speculate that shortages in available TK, not in using it, are an important source of poor comprehension among SPCs.

Previous research has found that even when SPCs have requisite knowledge, they are worse at applying that knowledge to answer inferential questions (Cain & Oakhill, 1999). Also, when good comprehenders and SPCs are trained on a knowledge base, they score similarly on literal questions but SPCs score worse at inferential questions (Cain et al., 2001). Though the present study did not specifically assess inferencing ability, it instead suggests that SPCs are able to use TK when they have it. This corroborates findings by Hua and Keenan (2014), who found that inferencing differences between controls and SPCs are due to differences in text memory rather than inferencing itself. When text memory is perfect, SPCs no longer show inferencing deficits as compared to controls.

Our findings also substantiate work by Compton et al. (2013), who also found no interactions between subgroups of readers with comprehension disabilities and passage-specific TK. Compton et al. used two methods for identifying subgroups of controls, early- and late-emerging poor comprehenders from their sample of 5th graders. While we found deficits in SPCs' TK availability, these authors did not investigate this question.

Still, both studies suggest that when SPCs have TK to aid in their memory for a text, they are able to use it. This provides support for the notion that TK deficits underlie poor comprehension, and that improving the breadth and depth of TK can help poor comprehenders understand what they read.

Chapter Five: Conclusions and Future Directions

This study extends findings of previous research by demonstrating that those with poorer comprehension also have less TK to draw from, by asserting that TK is a strong contributor to comprehension, and by demonstrating that its effects go beyond those of general knowledge, WM, and word decoding. These findings have implications for instruction and intervention.

Comprehension deficits contribute to children acquiring less reading experience, a factor that is related to impaired reading processes as well as developing a smaller knowledge base to support reading (Compton, Miller, Elleman, & Steacy, 2014). There is some controversy over the current practice of strategy-based interventions aimed at remediating poor comprehension, which have largely ignored the role of TK in comprehension (Compton et al., 2014) and instead focus on teaching basic, quantifiable skills such as word decoding. Compton et al. (2014) offer suggestions for building knowledge, including providing children various texts on the same topic to develop a better knowledge base. The current findings argue that TK is at least as vital to comprehension as individual skills, and supports recent literature calling for an increased emphasis on improving content knowledge in school curriculum (Kamhi, 2009; Compton et al., 2014).

One early study found positive effects of providing TK on comprehension for typical readers (Stephens, 1982), but no study has yet investigated whether this approach

would produce similar effects among SPCs. In the Stephens (1982) study, high school students read and answered questions on a passage to assess baseline comprehension performance. Then half of the students attended a lesson on the Texan War, which was designed not to provide any information that was included in later comprehension questions. The other participants received a lesson on the U.S. Civil War. Then, all participants read a passage and answered comprehension questions about the Battle of the Alamo. When scores on the first passage were covaried out, participants who received the lesson on the Texan War scored markedly better than those who had not. Results suggest that TK can be directly taught, and that it increases comprehension even when reading ability is accounted for.

More recent research has also provided evidence for the effectiveness of content-based instructional approaches over strategy-based approaches (McKeown, Beck, & Blake, 2009). The content approach engages readers with ideas from a text through open, meaning-based questions and discussion. This encourages readers to pursue meaning by evaluating each new idea in a text in terms of how it relates to previous information and TK. The strategy approach, in contrast, teaches students specific procedures such as summarizing and inferencing. When these two methods were evaluated, results indicated that content instruction corresponded to better recall quality as compared to recalls for students receiving strategy instruction or basal reading instruction (McKeown et al., 2009). Other work has also found that a content approach improves knowledge acquisition and reading comprehension among eighth-grade social studies students (Vaughn et al., 2013), a finding that has been replicated (Vaughn et al., 2015). Though

the work on content-based instructions has not included SPCs, these studies together with the results of the present dissertation suggest that increasing content knowledge may be successful at improving comprehension for struggling readers.

Much of the previous literature has failed to consider how TK coordinates with other cognitive abilities to produce comprehension. Thus, it has been unclear whether improving TK among subgroups of readers with deficits in other abilities could produce better comprehension. Though the present study is limited in its conclusions because we did not manipulate participants' levels of TK, we did not find evidence that weaknesses in WM and word decoding restrict participants' ability to draw on their TK for better recall, suggesting that improving TK may be an avenue for ameliorating poor comprehension. Additional research should examine whether improving TK in practice remediates poor comprehension among children with poor WM and word decoding abilities.

While our results show positive effects of TK on recall for poor comprehenders, there are likely additional group differences that lead to SPCs' comprehension deficits. Comprehension group differences in recall when TK, WM, and word decoding are considered may reflect differences in features such as attention, interest, and meta-comprehension, among others. Some limitations of the present research are that we did not assess these other variables. Furthermore, we only investigated the effect of TK for four passages. The passages used for the current study addressed academic information that is similar to the type of reading children do in school, but it is difficult to draw definitive conclusions without examining these results in terms of a variety of topics for

which children have varying levels of interest. Future studies should investigate these additional relevant factors that may mediate the relationship between TK and recall.

The question also remains as to whether passage modality is a factor that influences the relationship between TK and recall. Because listening tasks do not allow participants the opportunity to reread information they miss, they may place more strain on memory, encouraging participants to rely more heavily on TK to connect ideas and amplifying the effects of TK. The present study did not find differences in the effect of TK across reading and listening passages, but we used too few passages to make definitive conclusions about modality. Compton et al. (2013) did note a TK by passage modality interaction in that TK had a greater effect for listening passages, but their results are confounded because participants in their study had the most TK for reading passages. Future work should investigate possible differences in the relationship between TK and recall across reading and listening tasks.

Overall, the results of the present research are positive because they suggest an additional avenue for improving comprehension for poor comprehenders. Rather than concentrating on improving WM abilities, potential interventions should include expanding the depth and breadth of TK. While future work should experimentally test these effects by manipulating participants' levels of TK, the current research presents strong evidence for the positive effects of existing TK on recall both across the spectrum and among those with SPC. Studies examining how reader knowledge and other characteristics interact can increase understanding of the factors that underlie

comprehension and help to inform practices aimed at improving comprehension for SPCs.

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