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Evidence of an Intelligent Tutoring System as a Mindtool to Promote Strategic Memory of Expository Texts and Comprehension With Children in Grades 4 and 5

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Abstract

Reading and comprehending content area texts require learners to effectively select and encode with hierarchically strategic memory structures in order to combine new information with prior knowledge. Unfortunately, evidence from state and national tests shows that children fail to successfully navigate the reading comprehension challenges they face. Schools have struggled to find approaches that can help children succeed in this important task. Typical instruction in classrooms across the country has focused on procedural application of strategies or content-focused approaches that encourage rich discussions. Both approaches have achieved success but have limitations-related transparency and specificity of scaffolds and guidance for the teacher and learner in today's diverse and complex classroom settings. The text structure strategy combines content and strategy to provide pragmatic, transparent,

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and scaffolded instruction addressing these challenges. A web-based intelligent tutoring system for the text structure strategy, named ITSS, was designed and developed to provide consistent and high-quality instruction to learners in Grades 4 and 5 about how to read, select main ideas, encode strategic memory structures, make inferences, and monitor comprehension during reading. In this article, we synthesize results from two recent large-scale randomized controlled studies to showcase how the ITSS supports selection and encoding of students' strategic memory structures and how prior knowledge affects the memory structures. We provide greater depth of information about such processing than examined and reported in extant literature about overall increases in reading comprehension resulting from students using ITSS.

Keywords

quantitative, cognitive, empirical, learning environments, development, metacognition

Introduction

Strategic memory that is hierarchical, logically associated, and integrated with prior knowledge is a sought after attribute for academic, professional, and personal success. Experts from many domains were studied, and the most important differentiating feature between experts and novices was found to be hierarchical strategic memory (Chi, Feltovich, & Glaser, 1981; Wijekumar & Jonassen, 2007). Expert chess players were shown to have a slew of moves and photographic memories of options and reactions to moves (Ericsson & Charness, 1994). Similarly, expert physicists were shown to impose structure on problems based on top-level view of the problem statement while novices got mired in the details of the problem and bottom-up processing. Hierarchical memory structures are particularly helpful in science domains, such as physics (Reif, 2008). Expert readers have also been studied and shown to have hierarchically and logically associated memory structures (Meyer, Brandt, & Bluth, 1980). This phenomenon is referred to as the situation model in the construction-integration model (van Dijk & Kintsch, 1983) and strategic memory in the text structure model of reading comprehension (Meyer, 1975). A prominent focus in K-12 classrooms is promoting reading comprehension which in turn depends on the selection of important ideas from the text, activating prior knowledge and connecting with new information, and encoding of the all-important strategic memory.

Unfortunately the ability to create hierarchical strategic memory when reading to comprehend has been an elusive goal for a majority of children in K-12 settings as evidenced by state and national tests. A review of the four recent administrations of the National Assessment of Educational Progress

(2007, 2009, 2011, 2013) shows that at fourth grade, over 33% of students are not proficient in reading comprehension. The numbers remain dismal as children progress through the school setting to higher grade levels. Addressing the reading comprehension challenge as early as possible is important for the academic success of the children.

An important milestone in reading content area, expository texts to comprehend happens in the upper elementary grades. Typically developing children are expected to transition from narrative texts to expository texts in Grades 4 and 5. The transition is a rocky road with many pitfalls for the learners in today's diverse, heterogeneous classroom settings. Expository texts are different from narrative texts in organization, vocabulary, and complexity. They do not have the plots, characters, and settings that children are most familiar with when they enter the upper elementary grades. Instead, fourth-grade children encounter content area texts focusing on complex facts, information, and organizations of text that are unfamiliar to them.

A large-scale randomized controlled study was conducted on a web-based intelligent tutoring system for the structure strategy (ITSS) to study the efficacy of the solution to the problems facing upper elementary students' strategic memory. Web-based intelligent tutoring systems can be conceptualized as the more recent descendants of the cognitive technologies (Pea, 1985) and mindtools (Jonassen, 1996) designed to reorganize mental functioning. Pea describes software that has "qualitatively changed both the content and flow of the cognitive processes engaged during human problem solving" (p. 6) and focuses on reorganizing mental functions. ITSS presents instruction about using five text structures in an intelligent tutoring medium with interactive modeling, practice, assessment, and feedback to scaffold learning. The focus of the study was children in Grades 4 and 5 and teaching them how to select and encode strategic memory from reading expository texts. The *teaching* was done by a web-based intelligent tutoring system designed to model, provide practice tasks, assess student responses, scaffold the learner, and provide feedback (Meyer & Wijekumar, 2007). The instructional model for ITSS was extracted from video-taped interactions between expert teachers and students. The approach taught to the students is a content-focused strategy referred to as the structure strategy (Meyer, 1975). So within the ITSS, environment children received one-on-one instruction about using signaling words to classify text structure (e.g., in contrast signifying the use of the comparison structure), selecting important ideas from the text in a main idea, and writing a full recall.

This article presents the theoretical basis, delivery of instruction about the text structure strategy using a web-based intelligent tutoring system, empirical results about strategic memory structures generated by students using the ITSS, effects of prior knowledge on learning to create strategic memory structures, and contextual information about the implementation of ITSS in school settings.

Background

The most important aspect of learning to read and comprehend texts is teaching the reader to exert effort in reading the text, carefully selecting important ideas, strengthening the connections between the most important ideas, activating prior knowledge about the topic, and integrating the new information with prior knowledge (Meyer, 1975; van den Broek, 2005; van Dijk & Kintsch, 1983). Many attempts have been made to improve content area reading comprehension by focusing on content-based or strategy-based instruction (McKeown, Beck, & Blake, 2009) in curricula and textbooks. The interventions reviewed by McKeown et al. (2009) and others (e.g., Block & Pressley, 2002) have focused on instructional activities, such as summarizing (van Dijk & Kintsch, 1983), questioning the author (McKeown et al., 2009), purpose for reading (Mason, 2013), and discussions. These approaches have focused on the instruction about reading to comprehend but do not provide explicit scaffolding of the strategic memory structures.

Generating hierarchical and strategic memory from text is the focus of the text structure model of reading comprehension proposed by Meyer (1975) with a focus on selection of important ideas and encoding of memory structures guided by five text structures (i.e., comparison, problem and solution, cause and effect, sequence, and description) and nested structures. The text structure strategy is the instructional application of the model developed and refined by Meyer and colleagues through 35+ years of research (e.g., Meyer et al., 1980; Meyer et al., 2002, 2010). The text structure model was acknowledged by the National Reading Panel (National Institute of Child Health and Human Development, 2000) and more recently garnering attention due to the Common Core State standards (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010). Text structures have also become a staple of language arts curricular and textbooks in recent years. Unfortunately, the text structures presented in textbooks proceduralize text structures as separate and distinct entities from summarizing, inferring, and elaborating with little guidance on strategic memory (Wijekumar, Meyer, & Lei, 2017). In contrast, the text structure strategy focuses on using the text structure as the foundational scaffold for the strategic memory that is reflected in the summary, inference, and elaborations. Simply learning the names and definitions of the text structures is not sufficient, but strategic and metacognitive knowledge of text structures is required along with learning signaling words or connectives that can explicitly cue the text structures in expository text.

In fact, Meyer et al. (1980) showed that learning names, definitions, and signaling words for the five text structures in 3 hours of instruction over 2 days did not result in effective use of the structure strategy. Instead, younger and older adult learners required further sessions of instruction modeling how to strategically use text structure to select and encode ideas in expository science or social studies texts in order to strategically use text structure to build effective and strategic memory. Additionally, they also required practice and feedback using this metacognitive knowledge using text structure signaling with many different kinds of expository texts. ITSS instruction was built following these procedures to teach children how to strategically use text structure to build hierarchical and effective memory structure integrating key ideas in text with relevant prior knowledge. Some initial resistance of some teachers with ITSS may result from the teachers' declarative knowledge of text structures learned through a basal reading series or college textbooks and their unfamiliarity with procedural knowledge about strategic use of text structure for helping children understand and remember important ideas in content area reading.

Focusing the Reader's Attention on Strategic Memory

The text structure strategy combines a content focus with strategy instruction and draws its antecedents from research on how expert readers organize their memory from reading texts. Early research showed that expert readers were able to select information from texts and carefully generate hierarchically organized strategic memory from the texts. These hierarchical memory structures were more efficient due to the chunking and were associated well using the logical relationships between the ideas (e.g., problem and solution). The text structure model shares most of the component processes identified by the construction-integration model (van Dijk & Kintsch, 1983) and landscape model of reading comprehension (Yeari & van den Broek, 2011). All three models focus on the memory structures, goals of building relationships between the ideas in the text and prior knowledge, and acknowledge differences between experts and novices.

The text structure strategy provides one possible representation of hierarchical memory structures through the relationships between text ideas using five text structures and nested structures. Within the hierarchical memory structures emphasis at the top level is placed on the major problem and solutions if the article uses the problem and solution text structure organization. Causes for the problem are also placed at the higher level in the hierarchical organization. Lower nodes within the memory structures may contain details about the problem and solutions. These hierarchical memory structures are a staple of all three models of reading comprehension and are also the focus of measures of reading comprehension.

In practice within school settings, students are asked to read, comprehend, and rely on their strategic memory when responding to questions from the teacher, peers, or in assessments. Memory structures are the basis for all human activity and are continuously being updated through interactions with the text and tasks. When children are given tests to measure reading comprehension, the questions are a proxy for figuring out what they have gathered from the text, how well they have organized their memory, whether they have attended to any missing information (e.g., bridging inferences—McNamara, O'Reilly, Rowe, Boonthum, & Levinstein, 2007), whether they are able to extend their knowledge and synthesize across multiple sources, and have developed a sufficiently deep understanding of the text to use it in future learning. One of the common test questions asked is to identify the main idea of the text or to summarize the text. These questions gauge how well the reader is able to sift the text and allow the gist to rise to the top (i.e., within the hierarchical memory). A child with a good grasp of the text will be able to identify the most important ideas, differentiate them from the less important details in the passage, and understand how the ideas are connected to form a hierarchical and logically organized memory structure. A child with poor understanding of the text will frequently select too many ideas as being important and lack any coherent organization or hierarchy to the text. Typically, children who do not comprehend well engage in knowledge telling where they recall words without much thought to the connections between the ideas.

Text Structure Strategy

The text structure strategy focuses instruction on selecting important ideas from the text based on explicitly signaled or implied relationships using five text structures. Signaling words in the passages guide the reader to identify the text structure and then proceed with scaffolding the integration of ideas into memory structures. In the biomes passage shown in Exhibit 1, there are descriptions of two types of biomes. As the reader encounters information about each biome, they have the option of memorizing the text as a series of descriptions or using a more strategic approach by comparing the biomes. This example showcases an expert's sophisticated approach to creating a powerful memory that supersedes the simple interpretation that the passage should be read and comprehended as a description of biomes. Instead, the strategic reader can take advantage of the parallel structures in the text to create a tree-like memory structure that is chunked, efficient, and carefully associated with specified relationships. This tree-like, hierarchically organized memory serves as a strong prior knowledge for future comparisons to new biomes. Such memory structures can also be used to monitor comprehension by traversing the tree to identify missing information. The tree also serves as a transparent example of what a strategic memory structure should look like to a novice learner. In content-focused instruction (e.g., McKeown et al., 2009), readers are asked to think about ideas in the text and ask questions, they are encouraged to have rich discussions about the topics. The structure strategy-based approach scaffolds these activities as well by guiding the discussions (e.g., discussion prompt from teacher—"Fewer people live in the desert biomes. What do you think is the cause for that?"). These are the hallmarks of the structure strategy that guide the creation of strategic memory that can be useful to novice learners in improving their reading comprehension.

Exhibit 1: Comparison Passage Used in ITSS

Comparing the Desert and Grassland Biomes

Earth is covered with many types of biomes. Biomes are groups of plants, animals, and other organisms that live together in a similar environment. Biomes vary based on the types of animals or plants that live in them, the climate, how much water is available, and how life survives. The desert biome is a dry place where temperatures can reach over 120°F. Animals have to have hard shells and rely on very little water. Plants have to keep a thick outer skin to prevent water from evaporating.

In contrast, the grassland biome is a pleasant environment where temperatures are comfortable for humans, animals, and plants alike.

Figure 1 shows how a novice reader's memory structure and main idea are loosely structured and lack any hierarchical organization. An expert reader's main idea shown in Figure 2 reflects the well-organized memory structure.

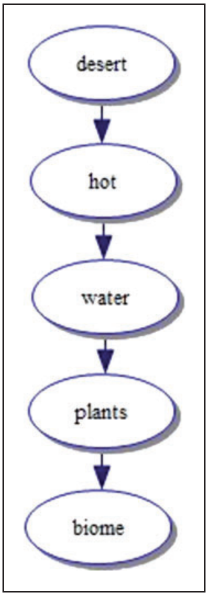

Figure 1. Novice reader's memory organization of the biomes text.

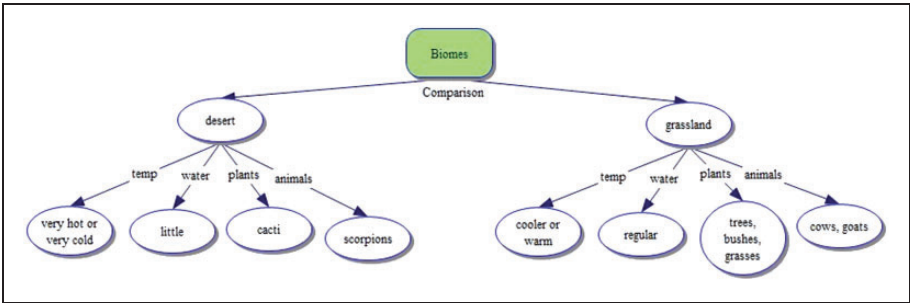

Figure 2. Expert reader's strategic memory structure about the biomes text.

When learning to use the structure strategy, readers are taught to look for important ideas based on the text structure and note the relationships between the ideas. Patterns for each type of text structure are used to scaffold these activities and support the main ideas and writing of full recalls.

The Web-Based ITSS

To consistently and widely disseminate the text structure strategy to learners in upper elementary grades, a web-based intelligent tutoring system was designed and developed (Meyer & Wijekumar, 2007). Web-based intelligent tutors are able to overcome variations in student background and teacher knowledge and skills by providing consistent high-quality modeling, practice tasks, built-in assessments, and strong and customized scaffolding and feedback to the learners. In developing the ITSS, expert human tutor models were observed and documented, interactions models were developed based on these observations, activity types were developed and sequenced to support the tutoring activities, and scaffolds and feedback were developed based on the observations, subject matter experts, and instructional designers (Wijekumar et al., 2014).

The system used well-signaled constructed passages, single text structure passages, nested text structure passages, and poorly signaled real-life passages to showcase how an expert would read and comprehend information. All passages were selected based on grade level (e.g., readability of Grade 2 for struggling readers and grade appropriate passages for others), interest (e.g., passages on science, social studies, sports to support students with varying interests), and types of reading tasks (e.g., writing a main idea, choosing whether the text was designed to inform or persuade).

A male-animated pedagogical agent named I.T. served as the teacher and read the passage, explained how he would select important ideas, wrote out sample main ideas, asked the students to engage in responding to his questions, and guided the student throughout the learning process. As I.T. initiated instruction, he presented modeling videos to the learner and then engaged the learner in practice tasks. Based on the correctness of the student response, he scaffolded the learner with feedback or an alternative passage with additional instructions. Initial thresholds for responses and logic for the responses were coded based on a pilot research study. Additional response patterns were updated as new responses were gathered during the large-scale research study.

Recent Research on ITSS

Two recently completed large-scale efficacy studies reported statistically significant and meaningful results with students in fourth- and fifth-grade classrooms (Wijekumar, Meyer, & Lei, 2012, Wijekumar et al., 2014). Results showed statistically significant effects on the standardized Gray Silent Reading Test (GSRT) at 4th grade (effect size [ES] = .10) and 5th grade (ES = .20). These ESs are small but meaningful due to the nature of the standardized test and in the context of other large-scale randomized studies on technology-based learning environments and reading curricula (e.g., Slavin, Cheung, Groff, & Lake, 2008). Larger effects were reported for researcher-designed measures of main idea and recall competence. Fifth graders in ITSS classrooms on average scored .42 *SD*s ($p < .05$) higher on comparison text structure signaling word identification task posttest scores than fifth graders not using ITSS. Also adjusted posttest scores were statistically significantly higher for fifth-grade students in ITSS classrooms than their control counterparts on all other researcher measures related to using the comparison text structure: writing a main idea (i.e., summary of passage) quality (ES = 0.53), writing a total recall of passage (ES = 0.32), and competence in using the comparison text structure in organizing their recall (e.g., using appropriate discourse markers to signal who or what was being compared; ES = 0.26; Wijekumar et al., 2014).

Current Study— Does ITSS Instruction Change Fourth- and Fifth-Graders' Strategic Memory?

Because of the importance of strategic memory and its role in reading comprehension, this research focuses on how ITSS changed the strategic memory of the learners participating in the research study. The main ideas written with the passage available for consultation and the full recalls written from memory serve as the data sources to gauge the students' memory structures. We present analyses of pre- to posttest changes on students' main idea competence and top-level structures (TLSs) as well as full-recall-based competence and TLSs in support of the premise that teaching the text structure strategy using the ITSS can reorganize the learners' strategic mental representation of expository texts.

Research

Research questions

1. Does the web-based ITSS instruction improve fourth- and fifth-grade students' memory structures represented in the recall of problem and solution text?
2. Does the web-based ITSS instruction improve fourth- and fifth-grade students' memory structures represented in full recall of the comparison text?
3. Does the web-based ITSS instruction improve fourth- and fifth-grade students' memory structures represented in comparison main ideas?
4. Does below grade level performance on pretest GSRT or prior knowledge about text structure interfere or promote hierarchical memory structures after ITSS instruction? That is, is there an interaction between ITSS instruction and pretest reading comprehension or prior knowledge about text structure?

Research Design

A school-based cluster randomized trial was conducted with 128 fourth-grade and 131 fifth-grade classrooms. Classrooms were stratified by school and randomly assigned to use the ITSS software as a partial substitute to the language arts curriculum for approximately 30 to 45 minutes a week or a business as usual control where there was no substitution of the language arts curriculum. The control group classrooms continued with their standard language arts lessons (without access to the ITSS software). This design preserved the total language arts instructional time with the only substitution being made for ITSS for approximately 30 to 45 minutes.

Participants

Schools were recruited using e-mail, regional presentations, and site visits by trained research administrators. Requirements for participation in the project included availability of computers for each child in the classrooms, software compatibility to the ITSS system, and sufficient bandwidth for full-classroom use of the software. The research team visited each volunteering school and explained the project goals to the teachers and received their consent to participate in the research study.

A total of 45 schools and 259 classrooms participated in the study. The participating schools were in rural and suburban locales with low numbers of racial or ethnic minorities (10%), and approximately 41% eligible to receive free- or reduced-price lunch.

All fourth- and fifth-grade teachers invited signed consents and agreed to participate in the study. All students in the teachers' classrooms were invited to participate, and approximately 5% declined to participate. The analysis sample included 1,944 Grade 4 students (989 in ITSS and 955 in control conditions) and 2,057 Grade 5 students (1,092 in ITSS and 965 in control conditions). There were similar percentages of female and male students in each grade level (49.23% female in Grade 4; 48.37% female in Grade 5).

Procedure

Pretests were administered at the beginning of the academic year, and posttests were administered under similar conditions at the end of the academic year to all students with permission. Measures included the standardized GSRT and researcher-designed measures. Tests were administered by the research team and supported by the teachers.

Students in the ITSS group used the software at least once a week for 30 to 45 minutes each week over a 6- to 7-month period starting immediately after the pretest. Teachers were supported by aides who checked on the computers and smooth functioning of the program.

Materials

Cognitive outcome for research questions. Reading comprehension was measured using a standardized reading comprehension test with multiple-choice questions about mainly short narrative texts. Reading comprehension also was measured using experimenter-designed recall and main idea tests about expository texts.

Standardized test of reading comprehension. The GSRT (Wiederholt & Blalock, 2000) Form B was administered at pretest, and Form A was administered at posttest. Pretest score on the GSRT was used as a covariate for data analyses and used to examine the effects of ITSS instruction on our dependent measures that focus on reading comprehension. Cronbach's alpha for both forms of the GSRT was reasonably high (alpha = .88). This test was used as measure of reading comprehension skill to identify students reading below, at, or above grade levels.

Experimenter-designed measures of strategic memory. Two equivalent test forms were created (Meyer et al., 2010), and one was administered before the children started ITSS and the second immediately after completing the program to test students' understanding of expository texts with problem and solution and comparison text structures. The problem and solution set of two equivalent passages had 98 words, 72 idea units, and equivalent scores on traditional measures of readability, text structure, and signaling (see Meyer, 2003). Each text presented a relatively unfamiliar problem and its cause and a solution that eliminated the cause of the problem about rats or dogs. The article about rats was an authentic newspaper article (see Meyer & Poon, 2001). Students were asked to recall all they can remember after reading each problem and solution text and placing it out of sight in an envelope. Interrater agreement between two scorers for this free recall task with the problem and solution set of texts (89%–98%).

Another equivalent set of two passages was also prepared for the comparison structure: (a) pygmy versus emperor monkeys and (b) Adelie versus Emperor Penguins. Each comparison passage had 128 words, 15 sentences, and 96 idea units. There were two tasks for the comparison structure: (a) a recall task like the recall task used for the problem and solution set of articles and (b) a comparison main idea task. For the main idea task, each student was asked to write a two-sentence main idea with the text available for consultation. Interrater reliability coefficients for the measures collected for the comparison free recall and main idea tasks (88%–99%).

The written performances on the main idea and free recall tasks were examined for evidence of well-organized memory structures. List-like structures with no evidence of hierarchical text structures were coded as 1 (e.g., TLS scores of 1 or 2, e.g., Meyer et al., 2010). Well-organized memory structures included main ideas or recall organized with the same text structure used by the authors was coded as a 3 (i.e., comparison, problem and solution, cause and effect, sequence with embedded causes or problems; Meyer et al., 2010). Written main ideas and recalls between these extremes were coded as 2 and can be characterized as list-like structures with part of the list including or hinting at a problem and solution, comparison, cause and effect, or sequence. Table 1 provided examples for each of the three memory structure categories for each task and text used in the study.

Data Analysis

To address the first three research questions, we used multinomial logistic regression using SAS to test whether students in the ITSS condition had higher probability of advancing to higher levels of organized memory structures than students in the business-as-usual control condition for each of the TLS and competence posttest measures from each of the recall problem and solution, recall comparison, and main idea comparison tasks. Students' gender (1 = female, 0 = male), initial reading level (1 = below grade level based on GSRT pretest, 0 = at or above grade level), the corresponding initial levels of organized memory structures-based pretest scores (i.e., 1 = low, 2 = middle, 3 = high TLS for TLS posttest measures or competence for competence posttest measures), and school locale (1 = rural, 0 = suburban) were controlled for in the models. Odds ratios for ITSS versus control conditions were reported for the odds of being in the middle-organized memory structure group (as opposed to the low group) and for the odds being in the high-organized memory structure

Table 1. Scoring for Evidence of Hierarchical Logically Organized Memory Structures.

Scoring scale for hierarchical logically organized memory structures	Examples for text structure, text topics, and task or activity
1 = no evidence: listing	Problem and Solution Text Structure (ps) (Topics – Rats or Dogs) and Writing a Full Recall of the Passage Without Consulting the Text(variables – pstls and psrte) • People using become allierice to these Rats & Mice. People take urine samples from the Animals • Physcatrits are trying to do allergies for mice and Ralts The doctor Andrew J. guy was a expert on allergies • Caniness that like the taste and smell of cocoa beans. The sponsor of the US. Navy was a pilagrouist that help people on their work. • I remember it had to do with carnen with cocoa or something then about puppies runming or something and the taste of cocoa. Comparison Text Struture (rc) (Topics – Penguins or Monkeys) and Task = Writing a Full Recall of the Passage Without Consulting the Text Variables rctls and rcrte • I rember that they said they can weigh over 90 pound and said they can be 4 feet tall. • The penguins That grow to 4 feet tall can way 90 pouns. All penguins come from all ather The world I Think. • There are rainforsts. There are monkys. • the pyeum monkes can grow up to 6 inches they pyeum monkes have v shaped jaws thats all i can remember Main Idea Comparison (mi) (topics – Penguins or Monkeys) Variables – mitls and mirte • monkeys eat bnanus. monkeys eat ticks off frome ater mokeys. • The main idea is about pygmy monkeys.
2 = Partial indication of organization	Recall Problem and Solution (Rats or Dogs) • People that pet mice and rats don't get squerted with urin to actavate there aligies. What the story is about is there are scientists that study off of rats mice. • Dogs get cocco beans if they are on a color. If dogs are on colors they will be checked. They will walk in gardens with black make feet. Dogs can be poisond they have cocco beans. They have to have a speisle kind of food thats not poisones.

(continued)

Table 1. Continued.

Scoring scale for hierarchical logically organized memory structures	Examples for text structure, text topics, and task or activity
	Recall Comparison (Penguins or Monkeys) • Adeline and other penquins are different. they eat krill. they only grow up to 2 feet. Last they have short feathered beaks and beady eyes. • First, I read that the smallist monkey is the pymgy. Secondly, I read that the pymgy lives in south amirca's warm rainforest. Then, It told me that the other monkey eats fruit. That is all I remember. Main Idea Comparison (Penguins or Monkeys) • emperor penguins are big from one anothers. • Emperor penguins are different from Adelie penguins. They both are strange. • The pygmy monkeys and the emperor monkeys have many differents.
3 = Evidence for well-organized memory structures	Recall Problem and Solution (Rats or Dogs) • Physicoligysts who work with rats and mice often become alergenic to thoes creashers this is a real hazerd to thoes who have to spend 1 or 2 weeks with them. the doctors at D.I.H. recamended to be nicer to them. • Rats and mice can make a kind of doctor very sick. These doctor get allergies from the rats and mice. Protein in the animal can be one cause. They had a meeting about this problem. They fixed the problem • Canines that like the taste and smell of cocoa bean shells become impaired after eating them. This becomes a hazard because they are poisoned. Dr. RFF suggest a muzzerd for puppies. Recall Comparison (Penguins or Monkeys) • This article is about two diffrent kinds of penguins and all about them. The empor penguins weigh about 90 pounds and grow about 4 feet tall. The Aldiene penguin is smaller and and grows to about 2 feet high. And can weigh 11 pounds. • Pygmy Monkeys are different from emporer monkeys because the Pygmy monkeys have V shaped jaws and emporer monkeys have U shaped jaws. They live in South America's Rainforest. Main Idea Comparison (Penguins or Monkeys) • to comparing Emperor penguins and Adelie penguins. by how the look color and different part about the body • The main idea is the differences between emperor and Adelie penguins. The differences are height, weight, and where they live. • The emperor mokeys are bigger than the pygmy mokeys are smaller. The pygmy mokeys do not eat fruits like the emPor mokeys.

group (as opposed to the middle one). We ran a two-level and three-level model acknowledging the multilevel nature of the dataset; however, the model would not converge. Therefore, we ran the single-level model for this analysis.

The fourth research question was addressed by adding interaction terms between experimental condition ($1 = ITSS$, $0 = control$) and initial reading level as well as between experimental condition and initial levels of organized memory structures to the previous main-effect models. Statistically significant interactions were plotted to examine the patterns of interactions.

Missing Data

There were 0.3% to 1.6% of students in Grade 4 and 0.2% to 0.9% of students in Grade 5 missing one or more of the posttest scores. Moreover, 2.5% of Grade 4 students and 3.4% of Grade 5 students missed the GSRT pretest, and 0.2% Grade 4 students also missed gender. Little's Missing Completely at Random Test failed to reject the hypothesis of missing completely at random for Grade 4 ($\chi^2 = 37.722$, $df = 26$, $p = .064$) but not for Grade 5 ($\chi^2 = 48.765$, $df = 26$, $p = .004$). Students missing the GSRT pretest tended to have slightly lower initial organized memory structure scores. Due to the small percentages of missing (<5%) and relatively large sample sizes, missing data were deleted listwise for each analysis model to maximize the sample size for each outcome variable. We included both initial reading (based on the GSRT pretest) and initial organized memory structure levels as covariates in the analysis models so that bias would be minimal (Graham, 2009).

Results

Table 2 presents fourth-grade and Table 3 presents fifth-grade descriptive statistics for all the variables used in the analysis. The variables include problem and solution text TLS, problem and solution text competence, comparison text TLS, comparison text competence, main idea TLS, and main idea competence.

Research Questions 1 to 3

Table 4 shows the logit estimates for ITSS and the corresponding odds ratios from the main-effect models. ITSS had a statistically significant effect on all posttest measures but problem and solution TLS for both grade levels after adjusting for students' gender, initial reading level, initial level of organized memory structures, and school locale. That is, students in the ITSS condition had higher odds of being in higher levels (as opposed to the adjacent lower level) of organized memory structures at posttest than students in the control condition after controlling for the covariates. Specifically, the odds of being in the high-organized memory structure level (vs. the middle level) as well as the odds

Table 2. Percentages of ITSS or Control Grade 4 Students in Each of the Pretest Organized Memory Structure Levels Transitioned to the Different Posttest Levels.

Posttest levels	Pretest low		Pretest middle		Pretest high	
Problem and solution top-level structure (Pstls)						
	ITSS ($n = 397$)	Control ($n = 390$)	ITSS ($n = 225$)	Control ($n = 226$)	ITSS ($n = 364$)	Control ($n = 337$)
Low	78.09	87.69	59.11	76.11	53.85	61.13
Middle	6.05	4.62	6.67	3.98	8.52	8.90
High	15.87	7.69	34.22	19.91	37.64	29.97
Problem and solution competence (Psrte)						
	ITSS ($n = 557$)	Control ($n = 544$)	ITSS ($n = 200$)	Control ($n = 187$)	ITSS ($n = 229$)	Control ($n = 222$)
Low	49.73	56.25	30	31.55	24.45	27.93
Middle	35.01	37.13	40.5	37.97	37.55	50.45
High	15.26	6.62	29.5	30.48	37.99	21.62
Comparison top-level structure (Rctls)						
	ITSS ($n = 389$)	Control ($n = 385$)	ITSS ($n = 221$)	Control ($n = 226$)	ITSS ($n = 356$)	Control ($n = 337$)
Low	31.36	43.38	15.84	21.68	8.71	10.68
Middle	28.28	26.49	21.72	28.76	21.35	22.55
High	40.36	30.13	62.44	49.56	69.94	66.77
Comparison competence (Rcrte)						
	ITSS ($n = 546$)	Control ($n = 539$)	ITSS ($n = 196$)	Control ($n = 187$)	ITSS ($n = 224$)	Control ($n = 222$)
Low	50.18	61.41	28.06	27.81	22.77	26.58
Middle	17.40	14.66	23.47	26.20	20.09	17.57
High	32.42	23.93	48.47	45.99	57.14	55.86
Main idea top-level structure (Mitls)						
	ITSS ($n = 389$)	Control ($n = 381$)	ITSS ($n = 222$)	Control ($n = 223$)	ITSS ($n = 360$)	Control ($n = 338$)
Low	35.22	55.91	22.07	39.91	15.83	30.18
Middle	41.39	32.02	57.21	51.57	53.06	57.10
High	23.39	12.07	20.72	8.52	31.11	12.72

(continued)

Table 2. Continued

Posttest levels	Pretest low		Pretest middle		Pretest high	
Main idea competence (Mirte)						
	ITSS (*n* = 546)	Control (*n* = 531)	ITSS (*n* = 199)	Control (*n* = 189)	ITSS (*n* = 226)	Control (*n* = 222)
Low	42.49	66.1	25.63	43.39	22.57	39.64
Middle	37.91	25.05	50.25	47.09	49.56	50
High	19.60	8.85	24.12	9.52	27.88	10.36

ITSS = intelligent tutoring system for the structure strategy.

Table 3. Percentages of ITSS or Control Grade 5 Students in Each of the Pretest Organized Memory Structure Levels Transitioned to the Different Posttest Levels.

Posttest levels	Pretest low		Pretest middle		Pretest high	
Problem and solution top-level structure (Pstls)						
	ITSS (*n* = 246)	Control (*n* = 269)	ITSS (*n* = 280)	Control (*n* = 263)	ITSS (*n* = 561)	Control (*n* = 433)
Low	70.73	77.70	55.36	66.16	40.64	51.04
Middle	7.72	5.58	5.71	7.22	5.35	5.77
High	21.54	16.73	38.93	26.62	54.01	43.19
Problem and solution competence (Psrte)						
	ITSS (*n* = 428)	Control (*n* = 455)	ITSS (*n* = 275	Control (*n* = 203)	ITSS (*n* = 384)	Control (*n* = 307)
Low	40.19	45.49	21.82	25.12	17.19	20.85
Middle	37.85	37.36	38.91	44.83	31.25	36.81
High	21.96	17.14	39.27	30.05	51.56	42.35
Comparison top-level structure (Rctls)						
	ITSS (*n* = 247)	Control (*n* = 262)	ITSS (*n* = 281)	Control (*n* = 261)	ITSS (*n* = 560)	Control (*n* = 431)
Low	26.32	32.44	10.68	15.33	4.82	8.35
Middle	17.81	26.72	19.57	32.18	11.79	13.92
High	55.87	40.84	69.75	52.49	83.39	77.73

(continued)

Table 3. Continued

Posttest levels	Pretest low		Pretest middle		Pretest high	
Comparison competence (Rcrte)						
	ITSS ($n = 430$)	Control ($n = 447$)	ITSS ($n = 275$)	Control ($n = 201$)	ITSS ($n = 383$)	Control ($n = 306$)
Low	38.84	51.68	18.91	23.88	12.79	17.32
Middle	18.37	16.33	24.36	23.88	16.97	18.30
High	42.79	31.99	56.73	52.24	70.23	64.38
Main idea top-level structure (Mitls)						
	ITSS ($n = 246$)	Control ($n = 263$)	ITSS ($n = 281$)	Control ($n = 258$)	ITSS ($n = 559$)	Control ($n = 432$)
Low	33.33	44.49	14.59	26.74	10.91	22.45
Middle	45.53	41.83	59.43	58.14	53.31	65.28
High	21.14	13.69	25.98	15.12	35.78	12.27
Main idea competence (Mirte)						
	ITSS ($n = 429$)	Control ($n = 447$)	ITSS ($n = 275$)	Control ($n = 200$)	ITSS ($n = 382$)	Control ($n = 306$)
Low	35.43	52.35	20	35.5	13.61	29.08
Middle	45.69	36.24	53.82	51	50.79	60.78
High	18.88	11.41	26.18	13.5	35.6	10.13

ITSS = intelligent tutoring system for the structure strategy.

of being in the middle level (vs. low) were both statistically significantly higher for the ITSS group than for the control group on the following grade level and measures: Grade 4 comparison competence (odds ratio = 1.3 for high vs. middle; 1/.752 = 1.3 for middle vs. low), main idea TLS (odds ratio = 2.0 for high vs. middle; 1/.514 = 1.9 for middle vs. low), and main idea competence (odds ratio = 2.0 for high vs. middle; 1/.484 = 2.1 for middle vs. low); Grade 5 main idea competence (odds ratio = 2.2 for high vs. middle; 1/.55 = 1.8 for middle vs. low).

The odds of being in the high-organized memory structure level (vs. the middle level) was statistically significantly higher for the ITSS group than for the control group, but the odds of being in the middle level (vs. low) was not statistically significantly different, on the following grade level and measures: Grade 4 problem and solution competence (odds ratio = 1.7 for high vs. middle); Grade 5 problem and solution competence (odds ratio = 1.5 for high vs. middle) and comparison TLS (odds ratio = 1.8 for high vs. middle). In contrast, the odds of being in the middle-organized memory structure level (vs. the low level) was

Table 4. Multinomial Logistic Regression Effect Estimates for ITSS.

	Logit estimate (*SE*)		Odds ratio [95% CI]	
Outcomes	Low vs. Middle	High vs. Middle	Low vs. Middle	High vs. Middle
Grade 4				
Pstls	−0.34 (0.19)	0.22 (0.21)	0.710 [0.489, 1.032]	1.241 [0.827, 1.862]
Psrte	−0.03 (0.11)	0.54** (0.14)	0.974 [0.790, 1.200]	1.723 [1.319, 2.252]
Rctls	−0.28* (0.14)	0.24* (0.12)	0.752 [0.573, 0.987]	1.273 [1.014, 1.599]
Rcrte	−0.27* (0.13)	0.08 (0.13)	0.767 [0.590, 0.997]	1.086 [0.838, 1.408]
Mitls	−0.67** (0.11)	0.72** (0.14)	0.514 [0.413, 0.640]	2.049 [1.571, 2.674]
Mirte	−0.73** (0.11)	0.70** 0.15)	0.484 [0.392, 0.598]	2.009 [1.500, 2.690]
Grade 5				
Pstls	−0.17 (0.20)	0.34 (0.20)	0.845 [0.575, 1.243]	1.409 [0.945, 2.102]
Psrte	−0.07 (0.11)	0.38** (0.11)	0.936 [0.750, 1.168]	1.456 [1.165, 1.821]
Rctls	−0.01 (0.17)	0.57** (0.12)	0.992 [0.717, 1.372]	1.765 [1.389, 2.244]
Rcrte	−0.31* (0.14)	0.18 (0.12)	0.736 [0.563, 0.963]	1.199 [0.941, 1.528]
Mitls	−0.46** (0.12)	0.89 (0.12)	0.630 [0.498, 0.796]	2.434 [1.914, 3.095]
Mirte	−0.60** (0.11)	0.81** (0.13)	0.550 [0.443, 0.683]	2.241 [1.731, 2.901]

Note. Pstls = problem and solution top-level structure; Psrte = problem and solution competence; Rctls = comparison top-level structure; Rcrte = comparison competence; Mitls = main idea top-level structure; Mirte = main idea competence; ITSS = intelligent web-based tutoring system for the structure strategy; HLM = hierarchical linear modeling.
Covariates (students' gender, initial reading level, initial level of organized memory structures, and school locale) are included in the models but not shown in the table. Effect size = Adjusted difference between ITSS (coded 12) and control (coded – 12) groups divided by the student-level pooled standard deviation.
*Estimates are extracted from Model 1; degrees of freedom = 77.
$p < .05$. $^{**}p < .01$. $^{***}p < .001$.

statistically significantly higher for the ITSS group than for the control group, but the odds of being in the high level (vs. middle) was not statistically significantly different, on the following grade level and measures: Grade 4 comparison competence (odds ratio = 1/.767 or 1.3 for middle vs. low); Grade 5 comparison competence (odds ratio = 1/.736 or 1.4 for middle vs. low) and main idea TLS (odds ratio = 1/.63 or 1.6 for middle vs. low).

In short, ITSS generally had a positive effect in improving both Grade 4 and Grade 5 students' organized memory structures as indicated by most measures (except problem and solution TLS) included in this study. For students with similar demographic and reading backgrounds (i.e., gender, grade level, school locale, initial reading level, and initial organized memory structure level), those who participated in ITSS tended to have higher probabilities of being in the middle level or high level of organized memory structures or both (depending on

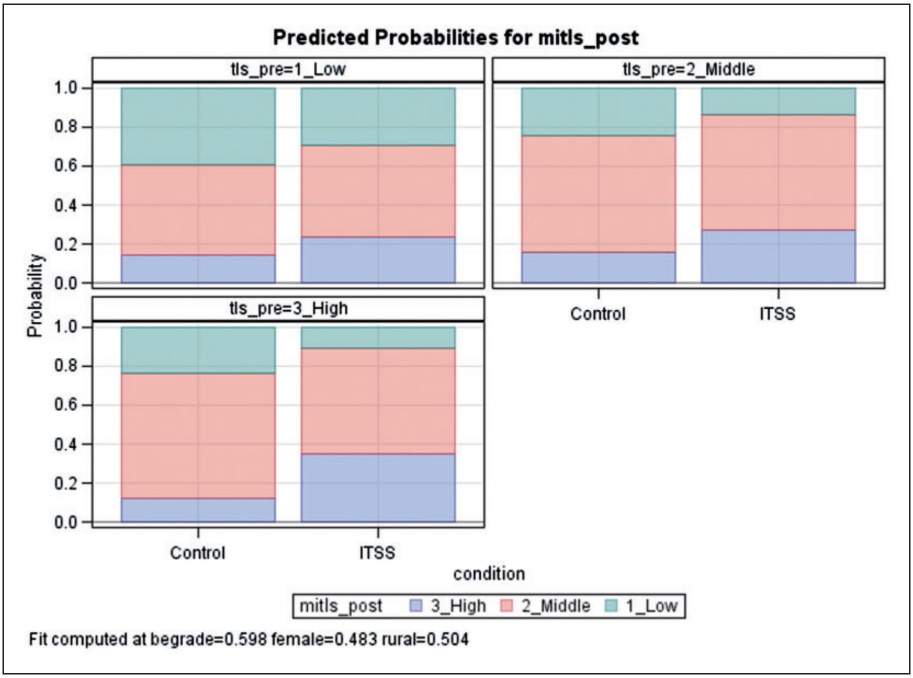

Figure 3. Interaction between experimental condition and initial organized memory structure level on Grade 5 posttest main idea top-level structure scores.

the specific posttest measures as specified above) than those who did not participate in ITSS.

Research Question 4

There was a statistically significant interaction between experimental condition and initial organized memory structure level on posttest main idea TLS (see Figure 3) and posttest main idea competence (see Figure 4) in Grade 5. Figures 3 and 4 show the similar interaction pattern on these measures that, holding other covariates (initial reading level, gender, school locale) constant, students in the ITSS condition had higher probabilities of being in the high-organized memory structure level than students in the control group and that the difference was larger for students having higher initial organized memory structure levels. These interactions suggested that ITSS was effective in improving Grade 5 students' organized memory structures on main idea (both TLS and competence) and more so for students having better initial organized memory structures. In other words, better initial organized memory structures enhanced the effect of ITSS in promoting hierarchical memory structures on main idea (or

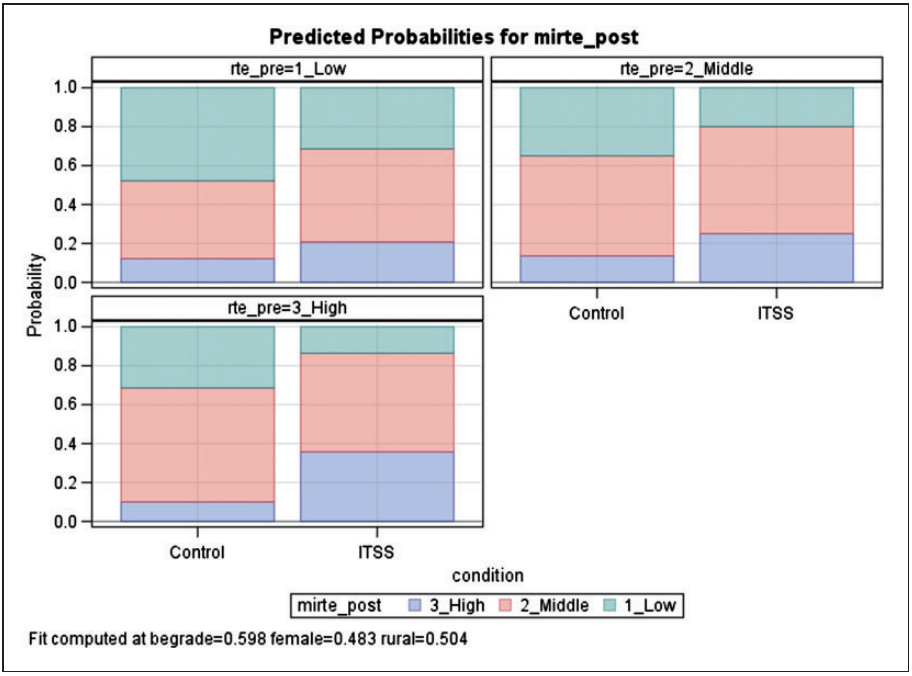

Figure 4. Interaction between experimental condition and initial organized memory structure level on Grade 5 posttest main idea competence scores.

Table 5. Jumps in Well-Organized Memory Structures for the Same Student Before and After ITSS.

Pretest	Posttest
1 = No Evidence: Listing • Cocao Bean can improv dog. U.S Dr. Res dogs, puppys death	**3** = Evidence for Well-organized Memory Structures • Pyoligist who most work with rats or mice are most likely to get disease. A British Doctor reacamends people to be nice to rats and mice. People who are nice and talk gently to there rats are less likely to have a reaction.
1 = No Evidence: Listing • I remember canidian pythologist. And also cocoa mucth, Dr. F.E.C, death situation, caines, and that's it.	**3** = Evidence for Well-organized Memory Structures • Many phiscians get allergic to rats and mice from experimenting. Dr. Andrew says, if not mean they will not urine on you.

(continued)

Table 5. Continued

Pretest	Posttest
1 = No Evidence: Listing • pymy monkeys are the most smallest monkeys they usaully eat sap from trees there teeth are shaped like a V for the to bite hard	**3** = Evidence for Well-organized Memory Structures • empereor penquins are tall the can grow up to be 4 feet tall and weigh up to 90 pound the Adeli penguin are small they are 2 feet tall and weigh about 11 pounds.
2 = Partial Indication of Organization • that there where to diffrent types of monkey	**3** = Evidence for Well-organized Memory Structures • Emperor and Alilah penguins are diffrent. Emperor penguins are tall and they eat fish I think. they Also live in the Ice pance of Antatica. unlike the emperor penguin the Alilah pencain is small the eat mostly krill. and also live on the Ice pance of Antartica

prior knowledge about text structure promoted hierarchical memory structures on main idea after ITSS instruction) for Grade 5 students. However, none of the other interactions between experimental condition and initial organized memory structure level or between experimental condition and initial reading level were statistically significant, indicating that the effect of ITSS (as discussed earlier) was generally consistent regardless of students' initial organized memory structure or reading levels.

Conclusion

Reading comprehension relies on the reader's ability to seek, select, and encode strategic memory of the texts. ITSS was designed to model, provide scaffolded practice, assessment, and feedback to learners on using the text structure strategy to achieve strategic memory of the text, thereby influencing reading comprehension. In the research and analysis reported here, we have presented evidence about how students learning the text structure strategy were able to select and encode more important ideas using a competence measure from both a main idea with passage in view and a full-recall written from memory. The results from the analysis shows that the odds of being in the high-strategic memory measures on the comparison text structure were statistically significant and higher for the ITSS class students at both fourth- and fifth-grade levels. The comparison text structure lessons were completed first, and most students had the opportunity to complete all the comparison lessons prior to the posttests. Samples of student responses with the scores and graphical representations of the written responses showcase the memory structures (Table 5).

In the context of today's fast-paced advances in computer technologies for learning, it is worth reflecting on seminal theories, research, and goals for the use of learning tools as presented by Pea (1985) and Jonassen (1996) and drawing parallels from those seminal ideas to the current work. The analysis presented here support the idea that this web-based intelligent tutoring system has been shown to reorganize mental functioning in creating strategic memory with fourth- and fifth-grade students when they read expository texts. Further, this evidence was gathered from young learners in Grades 4 and 5 where children typically experience difficulty in reading complex content area texts (e.g., Chall, Jacobs, & Baldwin, 1990). Thus, our development and research show promise for future extensions and development using both the computer tool as well as the text structure strategy.

This research shows promise that the ITSS intervention increased strategy use, and higher scores on strategy use were associated with better comprehension. These findings are also similar to converging evidence that strategy use is linked to better comprehension noted by numerous other research teams including Denton, Fletcher, Anthony, and Francis (2006), Mason (2013), McNamara et al. (2007), Wanzek, Wexler, Vaughn, and Ciullo (2010). These studies are a sample of many showing that reading comprehension strategies including those related to text structure, improve scores on standardized and researcher designed measures with children at different grades and reading levels. These studies used text structures or discourse markers in their strategy training and have reported small to large ESs.

This research has practical implications for teachers and developers of curricula. Memory structures are an important part of all reading comprehension interventions. While all the other approaches treat the text structure as an independent and separate activity for reading comprehension, the text structure strategy subsumes activities such as summarizing under the umbrella of text structures (Wijekumar et al., 2017). This analysis adds to the growing evidence-base about the use of the text structure strategy to improve reading comprehension (Meyer et al., 2010; Wijekumar et al., 2012, 2014; Williams, Stafford, Lauer, Hall, & Pollini, 2009). It also showcases how carefully designed intelligent tutoring systems can deliver instruction about text structures and make an impact on important academic tasks for elementary grade students.

Limitations of the study include the use of recalls as a proxy to what is going on inside the minds of the learners and focus on three types of text structures in this study. Further developments, data collection approaches, and experiments are necessary to seek a deeper understanding on the mental processes used by the learners for many different types of texts and grade levels. Finally, future studies should be conducted to measure strategy (mediator) and comprehension (outcome) at different time points during learning (to establish the causal direction) and after instruction to allow for a convincing test of this mediation effect.

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