ISSN 2380-727X

PSYCHOLOGY AND COGNITIVE SCIENCES

Open Journal

Openventio PUBLISHERS

Original Research

Working Memory Failures and Comprehension Monitoring Impairments in Primary Readers

Stephen K. Ntim, PhD, MPhil, MA, BEd*

Department of Social Science Education, Catholic University of Ghana (CUG), P. O. Box 363, Sunyani, Ghana

****Corresponding author***
Stephen K. Ntim, PhD, MPhil, MA, BEd
Faculty of Education, Department of Social Science Education, Catholic University of Ghana (CUG), P. O. Box 363, Sunyani, Ghana; E-mail: stephen.ntim@cug.edu.gh

Article information
Received: October 6th, 2023; **Revised:** October 26th, 2023; **Accepted:** October 30th, 2023; **Published:** November 3rd, 2023

Cite this article
Ntim SK. Working memory failures and comprehension monitoring impairments in primary readers. *Psychol Cogn Sci Open J*. 2023; 9(1): 17-26.
doi: 10.17140/PCSOJ-9-170

ABSTRACT

Background
This paper investigates the relationship between working memory (WM) failures and comprehension impairments in text comprehension among L2 primary readers in primary four through primary six in selected schools in Ghana.

Method
Five measures—decoding, vocabulary, working memory, comprehension monitoring, and reading comprehension—were used to test three research questions on the L2 primary reader's ability to notice inconsistencies in paragraphs, stronger academic language, re-reading times for mismatched words in sentences, and self-reporting and comprehension.

Results
Major findings were that the primary readers' ability to notice inconsistencies between paragraphs showed a significant average change between primary 4 and 5 in non-linear terms, with a correlation of r=-0.51 and a significant inverse correlation between the inability to see inconsistencies and the ability to recognize them. Vocabulary had a stronger positive relationship with comprehension monitoring (β=0.07, p<0.001) for primary five and six and primary four and five (β=0.04, p<0.001), respectively.

Conclusion
Decoding, vocabulary, and WM were found to be predominant factors for reading (β=0.46, p<0.00010), (β=0.37, p<0.0001), and (β=0.45, p<0.0001), while vocabulary and WM combination accounted for 25% of the additional reading variance in primary six, suggesting the significance of WM on self-reporting as a comprehension measure. The recommended classroom practice was for teachers to be mindful of working memory capacities, imposing mental demands on struggling L2 pupils.

Keywords
Working memory; Comprehension monitoring; Decoding; Vocabulary; Reading comprehension.

INTRODUCTION

The psychological concept of working memory (WM) dates back to the 1960s.[1,2] Over fifty years of scientific studies from psychology, biology, and/or neuroscience have been undertaken around this construct, even though psychology, biology, and neuroscience have still not arrived at a uniform categorization of its processes and functions.[3,4] Despite this, WM is implicated in all mental and cognitive work, such as reading, writing, computation, comprehension, etc. For example, reading is theorized to be the product of two subprocesses: word identification and linguistic (or auditory) comprehension.[5] Ample evidence exists to support this view from a diversity of alphabetic writings on the link between word identification and children's linguistic comprehension.[5,6]

Human WM has a critical role in facilitating the understanding of words we read, while impaired WM can make it more difficult to segment new text to understand given information on a page. What this means is that a reader struggling with impaired WM has challenges and difficulties with comprehension. A typical example is the Auditory WM which plays a critical function in reading. Auditory WM facilitates the recall of sounds and their associations with letters. When reading long, unfamiliar words from text, such as "cytoplasmic," the words have to be segmented into syllabi or sound chunks, such as cy-to-plasmic. As the little reader decodes the 'cy' and the 'to' simultaneously, the child holds the sounds in her or his mind until she or he works through 'plas' and 'mic' and connects the sounds together. What this means in practice is that the more proficient the Auditory WM of a child, the easier the process becomes for such a child. Thus, word recognition at the level of sensory memory (external receptors) plays a critical role in the early development of reading compared to linguistic comprehension. However, with time, the more fluent word reading becomes, the better language comprehension also takes shape as a source of reading skill.[7] Reading skills are critical to learning generally as children progress from primary to junior high.[8] Given that many rural children in Ghana perform abysmally in language at the Basic Examination Certificate,[9] there is increasing psycho-pedagogical interest to learn more about the component skills in memory and comprehension monitoring that contribute substantially to language comprehension.

Statement of the Problem

Ample research has been conducted for the last 30-years to monitor the exact nature of children's reading process and also how children on their own are able to evaluate their comprehension when engaged in reading.[10-14] Specifically, comprehension monitoring skills in reading are crucial in both contemporary literate society and school. A child who has the capability to self-assess metacognitively her understanding of a text, becoming conscious of unclear passages, is more likely to be a proficient reader and successful in school. The ability to think about how one is thinking as one reads a text, such as the ability to detect internal inconsistencies, has been observed as one of the distinguishing marks between proficient readers and less proficient readers.[15,16] This also explains the variance observed in reading comprehension development between the ages of 7 to 11-years. Research on deficient readers struggling with word identification and with poor reading comprehension confirms the notion that monitoring comprehension is essentially critical to reading.[15,16] The implication is that impoverished readers, compared to proficient readers, are generally deficient in monitoring their comprehension.[16]

Even though comprehension monitoring is critical to effective reading from primary four through five, few studies in Ghana have investigated the relationship between WM failures and comprehension monitoring impairments at this level. Additionally, comprehension monitoring as a metacognitive skill (which is not that one either has it or does not have it but develops as one goes through academic progression) is not too clear in the literature on how it develops through academic progression. The factors determining this are less well-known.

Few studies have examined the nexus between WM failures and comprehension impairments and their roles as potential foundational skills for predicting future poor reading capability in upper primary readers, besides word recognition in the study area. This study aims to fill this gap.

Research Questions

1. In what ways are primary readers able to notice inconsistencies in the first and second sentences of a paragraph?

2. What effect does stronger academic language (vocabulary, story recall, and academic knowledge) have on re-reading times for mismatched words in sentences?

3. How does self-reporting in early readers influence comprehension monitoring?

THEORETICAL FOUNDATIONS/LITERATURE REVIEW

Development of Comprehension Monitoring and Primary Readers

Monitoring comprehension is a complex cognitive skill. Nevertheless, it has been empirically verified that as early as the preschool period, one could observe prototypical monitoring behaviors with children under the age of 3-years, when the sequence of events in well-known stories is changed.[17] Then, between ages 8 and 11, comprehension monitoring becomes more improved.[18] Empirical studies on children's errors show some high improvements among 5-year-olds in comprehension monitoring, with improvement observed at the age of 11.[19] At the empirical level, three models have examined how comprehension monitoring contributes to reading. The first group of studies examined concurrent relations and children's comprehension monitoring when other variables such as vocabulary and WM were controlled.[20-22] Other groups of studies have also investigated comprehension, with children having difficulties understanding what they read due to the challenges of identifying internal inconsistencies. This inability is an indication of poor text integration and insufficient mental construction of what they read.[4,23] Still, other studies investigated WM as the storage and processing of information concurrently from a text. These combined processes are critical for relating new incoming information to already-existing models in the mind. This model gives a theoretical underpinning for the connection between WM and reading comprehension generally, as well as comprehension monitoring in particular.[21] It is particularly interesting to underscore the fact that in the literature, skills in monitoring comprehension explain the specific difference in reading measures in the ages of 8, 9 and 11-years and above of WM to reading. Findings such as this show that WM by itself is insufficient for skilled reading. A higher-level metacognitive process plays a critical role in predicting comprehension, both in reading and listening.[20-22]

Another important variable has to do with vocabulary knowledge as a critical predicting factor for both reading comprehension and skills in monitoring comprehension.[24] Nevertheless, vocabulary is never a stand-alone variable, and it is intimately connected to WM.[23,25] Recent studies on inference-making suggest the mediating roles of WM capacity and the size of vocabulary. Therefore, any attempt to understand the nexus between monitoring comprehension and, by implication, any comprehension impairment and reading comprehension correlates, such as WM and vocabulary, needs to be controlled for associated variance.

Comprehension Monitoring and Text Comprehension

Text comprehension is contingent upon the reader's ability to mentally construct textual information. To do this, the reader has to go beyond literal words and sentences and integrate the meanings of words and sentences coherently.[26,27] What is more important is that as the reading of the text unfolds, there are continuous refinements, and readers and listeners successively connect concepts and ideas into the mental representation.[28] Therefore, seeing the text as both integrative and dynamic is essential to comprehension. What this means is that theoretically, comprehension monitoring or metacognition is critically constitutive in constructing a mental representation of what one is reading. Readers who consistently monitor what they are reading in the context of coherent mental representation will be better able to identify at what point in the reading they fail to know the meaning of some words, at what point in the reading the text fails to synergize with their previous knowledge, as well as when some information in the text can hardly come together to make meaning.

In situations such as these, readers with better monitoring skills are not only conscious of failure in comprehension, but more critically, they are able to take effective action to remedy gaps, such as re-reading the text, posing questions, making inferences, or cross-checking the meanings of unfamiliar words.[29] Thus, what is theoretically evident in the literature on reading psychology is this: evaluating one's comprehension during reading is significantly connected with integrative processes critical to constructing a coherent mental representation.[30] On the other hand, readers who process text without synchronizing propositions and ideas into a coherent whole but serially, such as word-by-word or sentence-by-sentence, fail to detect conflicts. This impairs comprehension monitoring. Comprehension monitoring is then theorized as a higher-level linguistic skill that is distinct from such lower linguistic skills as vocabulary and grammar.

Comprehension Monitoring and Reading through Eye-tracking with Early Readers Learning English as L2

Literacy skills, such as reading a complex matter involving a lot of cognitive processes such as letter identification, combining letters to form words, and sounding them in the form of phenomena, as well as other linguistic skills[31]; for example, (1) lexical and syntactic competencies,[32] (2) integrating information from prior knowledge and from text,[33] (3) inference making,[14] (4) disregarding non-relevant information,[30] (5) readers' motivation[34] and (6) metacognitive abilities.[35] Metacognition is crucially important for this current study since text comprehension monitoring is a critical component of metacognition. In particular, procedural metacognition[36] is underscored by two mental processes: monitoring and control. Understandably, then, learning to read can be challenging for many early readers learning English as L2, using the maternal language in the home.[37] Using English as an L2 proficiency is significantly related to success in formal education.[38-40] Therefore, it is critical to understand these challenges. Children learning English as L2 compared to native or monolinguals often lag behind in reading comprehension. This is often linked to deficits in vocabulary size and depth.[36,38-46] However, when it comes to comprehension monitoring, there is some evidence that learners of English as L2 or English Additional (EAL) tend generally to be less adeptly reactive to L1. They lag behind in metacognition processes such as checking and regulating whether or not they understand figurative and multi-word phrases.[47]

Many empirical studies assume that the reader's ability to notice and react to mismatches between the reader's background knowledge and text information in reading[48] or in the view of other authors, between the reader's interpretation of previous knowledge and later text segmentation constitutes comprehension monitoring.[49,50] A typical approach to measuring comprehension monitoring is that children are asked to identify a mismatch inserted into a text, such as a syntactic mismatch between a pronoun and a verb. It could also be a mismatch between text information and respondents' ability to verbalize or underline the inconsistency.[9,16,51-53] Such studies demonstrate a significant relationship between comprehension and monitoring ability; in older children, skilled readers tend to have better comprehension and monitoring skills than younger children or less skilled readers.[15,16,19,54] L2 learners of English, relative to L1, have been identified as being less likely to notice inconsistencies in the interpretation of figurative phrases and the story context.[47]

Besides, children with reading disorders are seen in reading comprehension to have a better predisposition than normal children to monitor their understanding of written text.[55] Empirical evidence shows that children deficient in comprehending text due to challenges of language, WM, vocabulary, reason, etc. have also shown that metacognition (comprehension monitoring) may also be implicated.[56] Evidence-based examples have to do with poor and slower readers having poor post-judging confidence ratings of prior information. This is attributed to lower accessibility to the information stored, which also affects readers' confidence in their prior performance.[57-59]

MATERIALS AND METHODS

Participants

Participants were 150 pupils in the upper primary: primary four through primary six. They were enrolled in an eight-weekend (Friday evening-Saturday evening) online and on-site study designed to investigate whether or not there is a relationship between WM failures and comprehension monitoring impairments. Up to about 50 pupils, ranging from primary 4-6 were selected from each of the three (3) study sites in Kumasi, Bechem, and Sunyani in the 2022-2023 academic year. In the three study sites, pupils were enrolled for this study in their first, second, and third years of study from selected local schools. Language teachers in these primary grades were also invited to participate. Schools that consented to participate were given a recruitment package with a short questionnaire and parental consent form. Teachers also completed screening forms to exclude any pupils with severe disabilities such that they would be unable to communicate in English. Out of these 150 pupils, 60% (90) were males, and the remaining 40% (60) were females. Forty percent (40%) lived in homes where English was the language spoken, while a majority (60%) spoke both English and Akan in the homes. The overall socioeconomic background of children was working class (90%), while 10% were from middle-class educated families.

Procedures and Measures

The procedure involved the assessment of pupils' skills during each week of the six weeks of interaction. Prior to training, trainers had to complete training modules that were specific to particular measures, which included video narrative presentations and finishing online quizzes. Pupils were evaluated individually. Measures with responses and scores deemed complex were taped in audio. The subsequent five constructs were: (1) decoding, (2) vocabulary, (3) WM, (4) comprehension monitoring, and (5) reading comprehension. All five measures were assigned to all three grades of pupils who participated in the study.

Decoding: Decoding, as used in this study, was a latent variable with four measures. Two were from the woodcock reading mastery test—revised/normative update (WRMT-R/NU).[60] One test measured pupils' ability to apply phonic and structural analysis skills to not-so-familiar words. This consisted of 45 items, Reliability was 0.93. The second test was Word Identification. This measured pupils' ability to identify isolated written words. This contained 106 items. The first six consecutive correct answers were used as the basis for achievement, Reliability was 0.97. The third test, Word Reading Efficiency (TOWRE-2).[61] This measured the number of English words ranging from high to low that pupils could pronounce without any errors in 45-minutes, Reliability was 0.93.

Vocabulary: Vocabulary was measured using three variables: 1) expressive vocabulary test, Second Edition (EVT-2) uses standardized and norm-referenced tests to test expressive vocabulary. Participants were shown pictures and asked to give a word to label them, and then asked to give a word as a synonym for a target word. When both labels and synonyms were correct, the items were scored as correct using this scoring, (0=incorrect, 1=correct). The fourth test used the peabody picture vocabulary test (PPVT-4).[62] It tested receptive vocabulary. The assessor asked participants to point to a picture out of four after reading a word that corresponds to the target's word meaning, Internal consistency was found to be 0.97.

WM: The Woodcock-Johnson III NU Test of Cognitive Abilities[21] was used to test auditory WM. Participants were asked to store and manipulate information as they listened to stories with both digits and words. They were required to do some reordering this way: first naming the words and the digit that followed, such as 4 followed by cocoa followed by 1 lion, and at the same time holding the sequential order in which they were earlier presented (e.g., cocoa-lion 4-1). A recording device was used to monitor, ensuring that timing gaps were the same for all. The reliability coefficient for all age groups was 0.90-0.97 with internal consistency at 0.80.

Comprehension monitoring: This was tested by asking participants to identify inconsistencies. Eight test stories, either consistent or inconsistent, were used. Three (3) were consistent stories, while five (5) were inconsistent. An instance of an inconsistent story was: "*Last night Kwaku walked home through the park. There was no moonlight, so Kwaku could hardly see his way. Kwaku often takes this route home. He walked along a narrow path. The moon was so bright that it lit the way. Kwaku lives on the other side of the park. There was no moonlight, so Kwaku could hardly see his way. Kwaku often takes this route home. He walked along a narrow path.*"

Inconsistent stories were to find out: (a) whether the story made sense, and (b) what was not right with the story using the scoring grade (score=0) or correct (score=1) for this task, which ranged from 0 to 8 points.

Reading comprehension: This construct was measured with two instruments: The Woodcock Reading Mastery Test—Revised/Normative Updated (WRMT)[63] was used to test participants' reading comprehension in short passages; the Gates-MacGinitie Reading Test[64] was used to examine how well-participants could read.

RESULTS

Before applying multivariate analysis of variance (MANOVA) to test the assumptions for normality, linearity, univariate and multivariate outliers, homogeneity of variance-covariance matrices, and multicollinearity, we conducted a preliminary test. The various checks on the assumption that comprehension monitoring was dependent on WM detected no violations. We also tested gender differences in WM and comprehension monitoring using a one-way multivariate analysis of variance. We observed a statistically significant difference in the dependent variable between males and females on the combined dependent variables: $F (2, 257)=13.85$, $p=0.000$; Wilks' Lambda=0.90; partial eta squared=0.10. We considered the results for the dependent variable separately using the Bonferroni adjusted alpha level of 0.25 to arrive at statistical significance: the scores on WM ($F(1, 258)=27.25$, $p=0.000$, partial eta square=0.10). An inspection of the mean scores indicated that males reported a higher-level of attitude towards statistics (M=90.71, 12.48) than females (M=82.06, 13.85) (Tables 1, 2 and 3).

Grade Related Ability to Notice Inconsistencies between Paragraphs

This paper investigated whether or not WM failures negatively affect comprehension monitoring. To address this, the topic was broken into three research questions: 1) In what ways are early readers able to notice inconsistencies in the first and second sentences of a paragraph? 2) What effect does stronger academic language (vocabulary, story recall, and academic knowledge) have on re-reading times for mismatched words in sentences? and 3) How does self-reporting in upper primary readers influence comprehension monitoring?

What is evident in reading psychology is the link between readers' ability to integrate what they read into a coherent mental process.[30] Hence, the first question assessed the extent of integration with comprehension monitoring. The second research question measured whether or not the size of vocabulary, general academic knowledge of readers, and ability to recall what readers have read were associated with the WM processes. For example, if readers have difficulty with eye tracking, letter identification, combining letters to form words, or forming words to read sentences, some of these are deemed to be automatic processes at the perceptual level. Finally, the third question examined children's ability to self-report what they have read.

Table 1. *Descriptive Statistics of Children Assessment*

Measures	Range	N	Mean (SD)
Word attached raw (P/4)	6-39	100	112 (20.89)
Word Attach Standard (P/4)	97-139	100	117.36 (8.67)
Word Identification raw (P/4)	19-83	100	49.19 (12.71)
Word Identification Standard (P/4)	93-146	100	118.98 (11.59)
Sight Word Raw (P/4)	12-73	100	45.14(14.74)
Sight Word Standard (P/4)	71-142	100	108.346 (15.30)
Phenomics Decoding raw (P/4)	2-42	100	20.06 (10.69)
Phenomics Decoding standard (P/4)	69-145	100	103.67 (14.61)
Vocabulary			
EVT-2 Raw (P/4)	58-140	100	97.86 (13.78)
EVT-2 Standard (P/4)	76-147	100	108.54.(12.28)
PPVT-4 Raw (P/4)	87-195	100	130.59 (16.37)
PVT-4 Standard	82-160	100	111.876.8 (12.64)
CELF- 4 Word classes Receptive Raw (P/4)	10-21	100	19.03 (1.84)
CELF-4 Word classes Expressive (P/4)	7-20	100	115.14.(1.84.)
WJ- Auditory Memory raw (P/4)	0-86	100	4.56 (2.11)
WJ- Auditory Memory Standard (P/4)	81-152	100	113.22 (13.81)
Comprehension Monitoring			
Comprehension Monitoring (P/4)	0-8	100	4.56(2.11)
Comprehension Monitoring (P/5)	1-8	100	6.03 (1.65)
Comprehension Monitoring (P/6)	2-8		6.37 (1.43)
Reading Comprehension			
WRMT- Passage Comprehension raw (P/6)	23-53		37.95 (5.50)
WRMT Passage Comprehension Standard (P/6)	88-132		110.71 (9.33)
Gates Ma Ginite raw (P/6)	13-47		35.22 (8.42)
Gates MacGinite Standard (P/6)	2-9		59.3 (8.4)
Reading Comprehension			
Reading comprehension measure (P/6)	10-26		20.45 (4.04)

Note: WRMT=Woodcock Reading Mastery Test; EVT-2=Expressive Vocabulary Test; PPVT-4=Peabody Picture Vocabulary Test; G1=Grade 1; G2=Grade 2; Grade 3=Grade 3

Table 2. *Ability to Notice Inconsistencies between Paragraphs*

Measures	Range	N	Mean (SD)	Average Change between Grades	M Plus Growth (between Grades 4-5, 5-6)
Children's Grades					
Primary 4	73-93	100	4.55 (2.10)	t (107)=6.91, *p*<0.0001, d=0.67	r=0.34
Primary 5	86-105	100	6.02 (1.66)	t (107)=1.61, *p*<0.108, d=0.67	r=0.22
Primary 6	98-1118	100	6.35 (1.41)		
Across Board Performance of Groups between Skilled and Poor Readers					
Skilled readers	73-93	210	6.01(1.66)		r=-0.51
Poor readers	86-105	90	2.01 (3.66)		

Table 3. *Respondents' Scores on Working Memory and Comprehension Monitoring*

Dependent Variables	Males		Females		Between Subject-Effect			
	Mean	SD	Mean	SD	Df	M Sq	*F*-value	*p*-value
Working memory score	90.71	12.48	82.06	13.85	1	4622.82	27.25	0.000*
Comprehension monitoring score	39.87	8.29	37.90	9.34	1	240.49	3.10	0.075

The overall purpose of this paper was to investigate whether or not WM failures negatively affect comprehension monitoring. To address this, this study broke the topic into three research questions: 1) In what ways are early readers able to notice inconsistencies in the first and second sentences of a paragraph? 2) What effect does stronger academic language (vocabulary, story recall, and academic knowledge) have on re-reading times for mismatched words in sentences? and 3) How does self-reporting in upper primary readers influence comprehension monitoring? What has become evident in reading psychology is that text comprehension is directly linked with readers' ability to integrate what they read into a coherent mental process.[30] Hence, the first question on readers' ability to notice or fail to notice inconsistencies in related sentences was to assess the extent of integration with comprehension monitoring. Further, the second research question sought to measure whether or not the size of vocabulary, general academic knowledge of readers, and ability to recall what readers have read were associated with the WM processes. For example, if readers have difficulty with eye tracking, letter identification, combining letters to form words, or forming words to read sentences, some of which are deemed to be automatic processes at the perceptual level, then reading becomes a bit more difficult at a much higher-level. Finally, the third question examined children's ability to self-report what they have read.

Ability to Notice Inconsistencies between Paragraphs

The results showed that the ability to recognize inconsistencies in paragraphs by pupils increased from primary four (M=4.55, SD=2.10) to primary 5 (M=6.02, SD=1.66) and primary 6 (M= 6.35, SD=1.41). There was an average change between grades. Significant changes between the two early grades of primary 4 and primary 5 were observed as follows (t (107)=6.91, $p<0.0001$, d=0.67) (t(106)=1.61, $p=0.108$, d=0.17) respectively. What these scores suggested was that this skill had increased. To further understand the growth in comprehension monitoring based on this increase in the ability to notice inconsistencies, we needed to isolate and investigate the variability at primary 4. A latent growth model in Mplus[65] was run. Across time, the pattern observed in the means of the ability to notice inconsistencies and hence the ability to monitor comprehension with time, the correlations between Primary 4 and Primary 5 (r=0.34) relative to Primary 5 and Primary 6 (r=0.22) offered more support for a trend that was non-linear.

In addition to the grade-level non-linear trend, across the board, participants were found to have performed far better in recognizing inconsistencies relative to those who performed poorly, the former (M=6.01, SD=1.66), and the latter (M=2.01, SD=3.66). The former were more than three times able to better monitor their comprehension. The correlation between the two groups was r=-0.51, indicating a significant inverse correlation between the inability to recognize inconsistencies and the ability to recognize consistencies.

Stronger Academic Language (vocabulary, story recall, academic knowledge) and Re-Reading Times for Mismatched Words in Sentences

The relationship between vocabulary and WM was measured across the three grade levels, focusing on the ability to recall stories and re-reading times for mismatched words in sentences. First, class-related changes in comprehension monitoring at all three levels were examined. Overall, there was an increase in monitoring comprehension. However, the growth in this construct was found to be faster between primary five and primary six than it was between primary four and primary five. So, there was reliable variance in the linear growth, apparently due to individual differences, such as the size of vocabulary and academic knowledge, which made higher graders perform better and quicker in re-reading times for mismatched words. Vocabulary and Comprehension monitoring had a stronger positive relationship ($\beta=0.07$, $p<0.001$) for primary five and primary six, while for primary four and five, it was found to be ($\beta=0.04$, $p<0.001$).

We tested whether this was similar to WM and the data indicated for primary five and six ($\beta=0.06$, $p<0.001$) and ($\beta=0.05$, $p<0.001$) for primary four and five, showing a close relationship between WM and Comprehension Monitoring. Again, this data showed the presence of reliable differences in linear growth parameters. In summary, these data suggest that comprehension monitoring increased significantly across grade levels from primary 4 through primary 6. However, with time, there was some deceleration based on vocabulary in the lower grades of primary four.

Self-Reporting in Primary Readers and Comprehension

This third question examined the reader's ability to do self-reporting in reading, which could predict both future reading and comprehension monitoring. This was informed by the first experiment, in which the increase in reading ability was not initially found to be entirely linear but non-linear. Three predictors were measured in primary four using the following constructs: decoding, vocabulary, and WM, focusing on an increase in comprehension monitoring. In primary four, decoding was found to be significant and a good predictor of reading comprehension ($\beta=0.77$, $p<0.0001$). This explained about 58% of primary-six reading comprehension. Vocabulary and WM models were included in the measure. Decoding continued to be a leading predictor for reading ($\beta=0.46$, $p<0.0001$), vocabulary ($\beta=0.37$, $p<0.0001$) and WM ($\beta=0.45$, $p<0.0001$). Combining vocabulary and WM accounted for about 25% of the increased reading variance in primary six. When primary four pupils decoding, vocabulary, and WM were controlled, their reading comprehension at primary six was predicted to be ($\beta=0.38$, $p<0.001$). Additionally, comprehension monitoring was uniquely responsible for explaining an additional 8% of the variance in reading comprehension in primary six.

DISCUSSION

The findings of this study are consistent with other empirical studies showing that WM is directly related to children's reading comprehension as well as in adults.[66,67] Given that reading is a combination of integrating knowledge and skills such as decoding, vocabulary size, and syntactic and semantic processing, the findings reported here, in which WM has been consistently found to be correlated to decoding and vocabulary ($\beta=0.45$, $p<0.0001$) point to the significance of this construct in reading comprehension. What this finding means in practice is that at the elementary perceptual level of reading, involving processes such as decoding (eye tracking), identifying letters, combining letters to form words, combining words to form sentences, etc., a reader has challenges; at a higher-level of reading one sentence after another to integrate meaning, one would have exhausted attentional resources to make meaning.[27-29] This situation of memory failures becomes more critical at the higher-level of processing, such as monitoring one's comprehension to find out if one has understood what is being read, which becomes even more challenging.[26] The findings in this study were consistent in that, for each construct assessed to find a correlation between decoding and WM, the correlation was almost related. For example, when measuring the three constructs of decoding, vocabulary, and WM in the third research question, decoding continued to be a leading predictor for reading (β=0.46, p<0.0001), vocabulary (β=0.37, p<0.0001) and WM (β=0.45, p<0.0001). Combining vocabulary and WM, the latter was found to account for about 25% of the additional reading variance in primary six.

Similarly, in the second research question, vocabulary had a stronger positive relationship with comprehension monitoring (β=0.07, p<0.001) for primary five and primary six, while primary four and five were found to have a (β=0.04, p<0.001 an indication of the grade/age relationship, which was found to be linear. This particular finding was in direct contradiction to the finding of Yeoman[68] in which this author found a non-linear correlation between first- and second-grade readers and second- and third-graders. Again, testing this in relation to WM, there was a close relationship for primary five and six (β=0.06, p<0.001) and (β=0.05, p<0.001) for primary four and five, showing some close relationship of WM to comprehension monitoring.

In general, the participants of this study, who were all L2 learners of English, compared to those who used the native language more in their homes than L2, lacked metacognitive processes such as self-reporting, which confirmed.[69] Whereas those who used L2 frequently in the homes were about three times better at recognizing mismatches and better at interpreting previous and later text segmentation, which constituted comprehension monitoring[49,50,70] it was less so across the three grades for those who used more of L1. This implies that WM failures precipitated by L1 also impaired comprehension monitoring in L2. This finding supports the theory of Nugba et al[71] that since WM reflects ability in attention control, readers with high WM tend to have more resources for attentional control to focus on primary tasks. This finding also complements that of Yeomans-Maldonado[72] of mind wandering, especially dealing with demanding reading.

Interventions for L2 Children with Reading Difficulty and Language Teacher Education

Challenges with literacy acquisition, especially reading, in many Ghanaian basic schools could be attributed to WM challenges. Based on the findings of this paper, the subsequent three pedagogical interventions are being suggested: First, teacher education needs to focus on increasing teacher trainees' awareness of WM problems. Most teachers appear to be unaware of WM capacities and that children with impaired WM have memory failures that begin to manifest in poor reading acquisition. Second, teacher education needs to expose teacher trainees more than ever to adopt a form of teaching aimed at reducing memory loads, especially for already struggling students. Precisely because poor-reading pupils or students typically have problems related to lower perceptual processes in reading such as de-codification (letter and word identification as well as phenomes), it appears to be pedagogically more pragmatic to use audio to teach these lower processes first for pupils struggling with them. When these lower processes have become automatic, then teachers expose them to print text. This approach would be a strategy to adapt the child's environment to minimize memory load and enhance classroom learning. This is especially true when we have instances of some disadvantaged children from rural home backgrounds who are more used to oral communication than printed communication, and they carry this initial disadvantage to learning L2. The third approach would be for reading teachers to teach children to use memory strategies to improve the efficiency of their working memories.

Additionally, an integral part of supporting children who have deficient WM in the classroom would be for teachers to monitor students, especially struggling ones, on how they cope with mentally challenging activities demanding more mental load in such areas as mathematics and science. The fourth approach would be for teachers to assess students' learning activities to identify possible areas that are likely to be problematic for children with small WM capacities, such as a) activities imposing heavy mental demands on WM; b) those that are too long or have long sentences and paragraphs; and c) those having a large chunk of unfamiliar, complex, and difficult-to-understand material that imposes significant mental processing, especially in explaining complex concepts.

The findings in this study have underscored the correlation between WM and comprehension monitoring among children who use English as L2, measured along different constructs such as decoding, vocabulary, WM, comprehension monitoring, and reading comprehension. The overriding finding is that WM plays a critical role in digesting words, especially in monitoring comprehension. Deficient WM makes decoding new text cumbersome since WM reflects attention-control abilities. This means that individuals with more attentional control resources are more capable of focusing on primary tasks while simultaneously engaging in metacognitive processes than those with less attentional control resources.

REFERENCES

1. Baddeley A. WM. *Current Biology.* 2010; 20: R136-R140. doi: 10.1016/j.cub.2009.12.014

2. D'Esposito M, Postle BR. The cognitive neuroscience of WM. *Annu Rev Psychol.* 2015; 66: 115-142. doi: 10.1146/annurev-psych-010814-015031

3. Cowan N. What are the differences between long-term, short-term, and WM? *Prog Brain Res.* 2008; 169: 323-338. doi: 10.1016/S0079-6123(07)00020-9

4. Cowan N. *WM Capacity*. NY, USA: Psychology Press; 2005. doi: 10.4324/9780203342398

5. Hoover WA, Gough PB. The simple view of reading. *Read Writ*. 1990; 2: 127-160. doi: 10.1007/BF00401799

6. Protopapas A, Simos PG, Sideridis GD, Mouzaki A. The components of the simple view of reading: A confirmatory factor analysis. *Reading Psychology*. 2012; 33(3): 217-240. doi: 10.1080/02702711.2010.507626

7. Kershaw S, Schatschneider C. A latent variable approach to the simple view of reading. *Read Writ*. 2012; 25: 433-464. doi: 10.1007/s11145-010-9278-3

8. Garner R. *Metacognition and Reading Comprehension*. NY, USA: Ablex Publishing; 1987.

9. Jacobs JE, Paris SG. Children's metacognition about reading: Issues in definition, measurement, and instruction. *Educational Psychologist*. 1987; 22(3-4): 255-278. doi: 10.1080/00461520.1987.9653052

10. Pazzaglia F, Gyselinck V, Cornoldi C, De Beni R. Individual differences in spatial text processing. In: Gyselinck V, Pazzaglia F, eds. *From Mental Imagery to Spatial Cognition and Language: Essays in Honour of Michel Denis*. NY, USA: Psychology Press; 2012: 127-161.

11. Roebers CM, Schmid C, Roderer T. Metacognitive monitoring and control processes involved in primary school children's test performance. *Br J Educ Psychol*. 2009; 79(4): 749-767. doi: 10.1348/978185409X429842

12. Manchón RM, McBride S, Martínez MDM, Vasylets O. WM, L2 proficiency, and task complexity: Independent and interactive effects on L2 written performance. *Studies in Second Language Acquisition*. 2023; 45(3): 737-764. doi: 10.1017/S0272263123000141

13. Ntim SK. Comprehension skill differences between proficient and less proficient readers in word-to-text integration processes: Implications for interventions for students with reading problem. *International Journal of Learning, Teaching and Educational Research*. 2015; 13(3): 41-61.

14. Oakhill J, Hartt J, Samols D. Levels of comprehension monitoring and WM in good and poor comprehenders. *Read Writ*. 2005; 18(7-9): 657-686. doi: 10.1007/s11145-005-3355-z

15. Skarakis-Doyle E. Young children's detection of violations in familiar stories and emerging comprehension monitoring. *Discourse Processes*. 2002; 33(2): 175-197. doi: 10.1207/S15326950DP3302_04

16. Helder A, Van Leijenhorst L, van den Broek P. Coherence monitoring by good and poor comprehenders in elementary school: Comparing offline and online measures. *Learning and Individual Differences*. 2016; 48; 17-23. doi: 10.1016/j.lindif.2016.02.008

17. Baker L. Spontaneous versus instructed use of multiple standards for evaluating comprehension: Effects of age, reading proficiency, and type of standard. *J Exp Child Psychol*. 1984; 38(2): 289-311. doi: 10.1016/0022-0965(84)90127-9

18. Kim Y-SG. Direct and mediated effects of language and cognitive skills on comprehension of oral narrative texts (listening comprehension) for children. *J Exp Child Psycholy*. 2016; 141: 101-120. doi: 10.1016/j.jecp.2015.08.00

19. Strasser K, Del Rio F. The role of comprehension monitoring, theory of mind, and vocabulary depth in predicting story comprehension and recall of kindergarten children. *Reading Research Quarterly*. 2014; 49(2): 169-187. doi: 10.1002/rrq.68

20. Van Dyke JA, Johns CL, Kukona A. Low WM capacity is only spuriously related to poor reading comprehension. *Cognition*. 2014; 131(3): 373-403. doi: 10.1016/j.cognition.2014.01.007

21. Sidek HM, Aishah R. The role of vocabulary knowledge in reading comprehension: A cross-linguistic study. *Procedia - Social and Behavioral Sciences*. 2015; 197: 50-56. doi: 10.1016/j.sbspro.2015.07.046

22. Nation K, Adams JW, Bowyer-Crane CA, Snowling MJ. WM deficits in poor comprehenders reflect underlying language impairments. *J Exp Child Psychol*. 1999; 73(2): 139-58. doi: 10.1006/jecp.1999.2498

23. Johnson-Laird PN. *Mental Models: Towards a Cognitive Science of Language, Inference, and Consciousness*. MA, USA: Harvard University Press; 1983.

24. Van Dijk TA, Kintsch W. *Strategies of Discourse Comprehension*. NY, USA: Academic Press; 1983.

25. Rapp DN, Kendeou P. Revising what readers know: Updating text representations during narrative comprehension. *Mem Cognit*. 2007; 35(8): 2019-2032. doi: 10.3758/bf03192934

26. Markman EM. Comprehension monitoring. In: Dickson WP, ed. *Children's Oral Communication Skills*. NY, USA: Academic Press; 1981: 433-465.

27. Singer H. Validation in psychological. *Science*. 2013; 22(6): 361-366.

28. Castles A, Rastle K, Nation K. Ending the reading wars: Reading acquisition from novice to expert. *Psychol Sci Public Interest*. 2018; 19(1): 5-51. doi: 10.1177/1529100618772271

29. Cain K, Oakhill J. Profiles of children with specific reading comprehension difficulties. *Br J Educ Psychol*. 2006; 76(4): 683-696. doi: 10.1348/000709905X67610

30. Carretti B, Borella E, Cornoldi C, De Beni R. Role of WM in

explaining the performance of individuals with specific reading comprehension difficulties: A meta-analysis. *Learning and Individual Differences.* 2009; 19(2): 246-251. doi: 10.1016/j.lindif.2008.10.002

31. Guthrie JT, Wigfield A. How motivation fits into a science of reading. *Scientific Studies of Reading.* 1999; 3(3): 199-205. doi: 10.1207/s1532799xssr0303_1

32. Baker L, Brown AL. Metacognitive skills and reading. In: Pearson PD, Barr R, Kamil ML, Mosenthal P, eds. *Handbook of Reading Research.* New York, USA: Longman; 1984: 353-394.

33. Nelson TO, Narens L. Metamemory: A theoretical framework and new findings. *Psychology of Learning and Motivation.* 1990; 26: 125-173. doi: 10.1016/S0079-7421(08)60053-5

34. Spencer M, Wagner RK, Petscher Y. The reading comprehension and vocabulary knowledge of children with poor reading comprehension despite adequate decoding: Evidence from a regression-based matching approach. *J Educ Psychol.* 2019; 111(1): 1-14. doi: 10.1037/edu0000274

35. Strand S, Demie F. English language acquisition and educational attainment at the end of primary school. *Educational Studies.* 2005; 31(3): 275-291. doi: 10.1080/03055690500236613

36. Strand, S. and Hessel, A., English as an additional language, proficiency in English and pupils' educational achievement: An analysis of local authority data. 2018. doi: 10.13140/RG.2.2.20269.74727

37. Whiteside KE, Gooch D, Norbury CF. English language proficiency and early school attainment among children learning english as an additional language. *Child Dev.* 2017; 88(3): 812-827. doi: 10.1111/cdev.12615

38. Bowyer-Crane, Claudine, Silke Fricke, Blanca Schaefer, Arne Lervåg, and Charles Hulme. Early literacy and comprehension skills in children learning English as an additional language and monolingual children with language weaknesses. *Read Writ.* 2017; 30: 771-790. doi: 10.1007/s11145-016-9699-8

39. D'Angiulli A, Siegel LS, Serra E. The development of reading in English and Italian in bilingual children. *Applied Psycholinguistics.* 2001; 22(4): 479-507. doi: 10.1017/S0142716401004015

40. Hessel AK, Murphy VA. Understanding how time flies and what it means to be on cloud nine: English as an Additional Language (EAL) learners' metaphor comprehension. *J Child Lang.* 2019; 46(2): 265-291. doi: 10.1017/S0305000918000399

41. Lesaux NK, Rupp AA, Siegel LS. Growth in reading skills of children from diverse linguistic backgrounds: Findings from a 5-year longitudinal study. *Journal of Educational Psychology.* 2007; 99(4): 821-834. doi: 10.1037/0022-0663.99.4.821

42. Spätgens T, Schoonen R. The structure of developing semantic networks: Evidence from single and multiple nominal word associations in young monolingual and bilingual readers. *Applied Psycholinguistics.* 2020; 41(5): 1141-1169.

43. Verhoeven L. Components in early second language reading and spelling. *Scientific Studies of Reading.* 2000; 4(4): 313-330. doi: 10.1207/S1532799XSSR0404_4

44. Burgoyne K, Duff FJ, Clarke PJ, Buckley S, Snowling MJ, Hulme C. Efficacy of a reading and language intervention for children with Down syndrome: A randomized controlled trial. *J Child Psychol Psychiatry.* 2012; 53(10): 1044-1053. doi: 10.1111/j.1469-7610.2012.02557.x

45. van den Broek P, Kendeou P. Cognitive processes in comprehension of science texts: The role of co-activation in confronting misconceptions. *Applied Cognitive Psychology.* 2008; 22(3): 335-351. doi: 10.1002/acp.1418

46. Carpenter PA, Daneman M. Lexical retrieval and error recovery in reading: A model based on eye fixations. *Journal of Verbal Learning and Verbal Behavior.* 1981; 20(2): 137-160. doi: 10.1016/S0022-5371(81)90357-1

47. von der Malsburg T, Vasishth S, Kliegl R. Scanpaths in reading are informative about sentence processing. In: Proceedings of the First Workshop on Eye-tracking and Natural Language Processing. Mumbai, India; 2012; 37-54.

48. Kim Y-S, Phillips B. Cognitive correlates of listening comprehension. *Reading Research Quarterly.* 2014; 49(3): 269-281. doi: 10.1002/rrq.74

49. Meyers J, Lytle SL, Palladino D, Devenpeck G, Green M. Think-aloud protocol analysis: An investigation of reading comprehension strategies in fourth- and fifth-grade students. *Journal of Psychoeducational Assessment.* 1990; 8(2): 112-127. doi: 10.1177/073428299000800201

50. Pretorius E, Roux K. When comprehension barely occurs. In: *Tracking Changes in South African Reading Literacy Achievement.* Leiden, Netherlands: Brill Publisher; 2023: 88-120. doi: 10.1163/9789004687011_005

51. Zabrucky K, Ratner HH. Effects of reading ability on children's comprehension evaluation and regulation. *Journal of Reading Behavior.* 1989; 21(1): 69-83.

52. Cornoldi C. Metacognitive control processes and memory deficits in poor comprehenders. *Learning Disability Quarterly.* 1990; 13(4): 245-255. doi: 10.2307/1510351

53. Cornoldi C, Oakhill JV, eds. *Reading Comprehension Difficulties: Processes and Intervention.* NY, USA: Routledge; 1996. doi: 10.4324/9780203053324

54. Gernsbacher MA, Varner KR, Faust ME. Investigating differences in general comprehension skill. *J Exp Psychol Learn Mem Cogn*. 1990; 16(3): 430-445. doi: 10.1037/0278-7393.16.3.430

55. Koriat A. Monitoring one's own knowledge during study: A cue-utilization approach to judgments of learning. *J Exp Psychol Gen*. 1997; 126(4): 349-370. doi: 10.1037/0096-3445.126.4.349

56. Mirandola C, Del Prete F, Ghetti S, Cornoldi C. Recollection but not familiarity differentiates memory for text in students with and without learning difficulties. *Learning and Individual Differences*. 2011; 21(2): 206-209. doi: 10.1016/j.lindif.2010.12.001

57. Woodcock RW. Woodcock reading mastery tests, revised, examiner's manual. Karnataka, India: Pearson; 1998. https://pearsonclinical.in/solutions/woodcock-reading-mastery-tests-revised-normative-update-wrmt-r-nu/. Accessed October 4, 2023.

58. Torgesen JK, Wagner RK, Rashotte CA. Prevention and remediation of severe reading disabilities: Keeping the end in mind. *Scientific Studies of Reading*. 2009; 1(3): 217-234. doi: 10.1207/s1532799xssr0103_3

59. Dunn LM, Dunn DM. *Peabody Picture Vocabulary Test--*. APA PsycTests. 1997. doi: 10.1037/t15144-000

60. Woodcock RW, McGrew KS, Mather N, Schrank FA. *Woodcock-Johnson III Diagnostic Supplement to the Tests of Cognitive Abilities*. Itasca, IL, USA: Riverside Publishing Company; 2003: 10.

61. MacGinitie WH, MacGinitie RK, Maria K, and L. G. Dreyer. Gates-MacGinitie Reading Test. 4th ed. IL, USA: Riverside Publishing Company; 2000.

62. Muthén LK, Muthén BO. 1998–2012. Mplus : Statistical Analysis With Latent Variables: User's guide. Los Angeles, USA: Muthen & Muthen; 2012. https://www.statmodel.com/download/usersguide/Mplus%20user%20guide%20Ver_7_r6_web.pdf. Accessed October 4, 2023.

63. Daneman M, Merikle PM. WM and language comprehension: A meta-analysis. *Psychonomic Bulletin & Review*. 1996; 3(4): 422-433. doi: 10.3758/BF03214546

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

65. Burgoyne K, Whiteley HE, Hutchinson JM. The role of background knowledge in text comprehension for children learning English as an additional language. *Journal of Research in Reading*. 2013; 36(2): 132-148. doi: 10.1111/j.1467-9817.2011.01493.x

66. Christensen SC, Wright HH, Ratiu I. WM in aphasia: Peeling the onion. *Journal of Neurolinguistics*. 2018; 48: 117-132. doi: 10.1016/j.jneuroling.2018.02.001

67. Kane MJ, Engle RW. Working-memory capacity and the control of attention: the contributions of goal neglect, response competition, and task set to Stroop interference. *J Exp Psychol Gen*. 2003; 132(1): 47-70. doi: 10.1037/0096-3445.132.1.47

68. Rummel J, Boywitt DC. Controlling the stream of thought: WM capacity predicts adjustment of mind-wandering to situational demands. *Psychon Bull Rev*. 2014; 21: 1309-1315. doi: 10.3758/s13423-013-0580-3

69. Wendling BJ, Mather N, Schrank F. A Woodcock-Johnson III tests of cognitive abilities. In: Naglieri JA, Goldstein S, eds. *Practitioner's Guide to Assessing Intelligence and Achievement*. NJ, USA: John Wiley & Sons Inc.; 2009: 191-229.

70. Whitehurst GJ, Lonigan CJ. Child development and emergent literacy. *Child Dev*. 1998; 69(3): 848-872. doi: 10.2307/1132208

71. Nugba RM, Quansah F, Ankomah F, Tsey E, Ankoma-Sey VR, Rosemary V. A trend analysis of Junior High School Pupils'Performance in the Basic Education Certificate Examination (BECE) in Ghana. *International Journal of Elementary Education*. 2021; 10(3) : 79-86. doi: 10.11648/j.ijeedu.20211003.15

72. Yeomans-Maldonado G, Language and Reading Research Consortium (LARRC). Development of comprehension monitoring in beginner readers. *Read Writ*. 2017; 30(9): 2039-2067. doi: 10.1007/s11145-017-97