Education and Science

Original Article

Vol 47 (2022) No 211 249-271

The Contribution of Working Memory to Reading Fluency and Reading Comprehension Performance: Longitudinal Results

Cevriye Ergül [1], Gözde Akoğlu[2], Meral Çilem Ökcün Akçamuş[3], Burcu Kılıç Tülü[4], Zeynep Bahap Kudret[5], Ergül Demir[6]

Abstract

Working memory, which is an important determinant of learning capacity, is a structure that affects the acquisition and development process of many academic skills, especially reading and writing. On the other hand, it is stated that the effect of working memory on these skills differs according to grade levels. The effect of the verbal and visual components of working memory creates different effects in different dimensions such as fluent reading and comprehension, and the orthographic characteristics of a language are an important determinant on the level of this effect. From this point of view, this study aims to examine longitudinally the prediction of first- and second-grade participants' reading fluency and reading comprehension performances in terms of their verbal and visual working memory performances. These participants were evaluated in the kindergarten in a transparent orthography with an extremely high letter-sound relationship like Turkish. The research was carried out in schools that were randomly assigned from each stratum, representing the lower-middle and upper socioeconomic levels in the province of Ankara. The participants in the study consisted of 450 children (224 girls, 250 boys) who were aged five (Mean= 66.29 months, SD= 3.91) at the beginning of the study and who were not diagnosed with any cognitive and/or sensory disability. Measurements of the working memory performance of the participants in the kindergarten were conducted using the Working Memory Scale (WMS), and the measurements of the reading fluency and reading comprehension performances in the first and second grades were carried out using the Literacy Evaluation Battery (LAB). The results obtained from the study, in which working memory measurements were determined to predict reading fluency and reading comprehension skills, using the structural equation model, revealed that reading

Keywords

Working memory
Verbal working memory
Visual working memory
Reading fluency
Reading comprehension

Article Info

Received: 03.18.2021
Accepted: 01.18.2022
Online Published: 02.04.2022

DOI: 10.15390/EB.2022.10701

[1] Ankara University, Faculty of Educational Sciences, Special Education, Turkey, cergul@ankara.edu.tr
[2] İzmir Katip Çelebi University, Faculty of Health Sciences, Department of Child Development, Turkey, gzdakoglu@gmail.com
[3] Ankara University, Faculty of Educational Sciences, Special Education, Turkey, okcun@ankara.edu.tr
[4] Ankara University, Faculty of Educational Sciences, Special Education, Turkey, tulu@ankara.edu.tr
[5] Ankara University, Faculty of Educational Sciences, Special Education, Turkey, zkudret@ankara.edu.tr
[6] Ankara University, Faculty of Educational Sciences, Department of Educational Sciences, Turkey, erguldemir@ankara.edu.tr

fluency and reading comprehension performances increased from the first grade to the second grade and from the fall semester to the spring semester at each grade level. The results also showed that the verbal and visual working memory performance in the kindergarten contributed to the reading fluency and reading comprehension success of the first and second grades in the fall and spring semesters at different levels.

Introduction

The acquisition of reading and writing skills is of great importance both academically and socially, and working memory, which is one of the most important determinants of learning capacity, affects the acquisition and development of many academic skills, especially the acquisition and development of reading and writing skills. Working memory is a system with limited capacity in which information is stored and processed for a short time, while engaging in cognitively challenging activities (Baddeley, 2003; Ergül, Yılmaz, & Demir, 2018). Unlike short-term memory, which is considered as a passive information storage system, working memory refers to a system in which storage and processing occur simultaneously across a large number of academic activities, from complex subjects such as reading comprehension and mental arithmetic, to relatively easy skills such as copying a piece of writing from the board.

Although there are different theoretical approaches to explaining the working memory as a processor that can quickly access information required for cognitive activity, the multi-component working memory model proposed by Baddeley and Hitch (1976) is widely accepted in the related literature (Baddeley, 2000, 2003; Baddeley & Hitch, 1976). According to this model, working memory consists of different components that undertake three basic functions, namely temporary verbal storage, temporary visual-spatial storage and coordination function, which are separate from one other but interact with one other (Montgomery, Magimairaj, & Finney, 2010). The central executive, which is one of the components, is in a mutual relationship with the other two components called the phonological loop and the visual-spatial sketchpad. The phonological loop is defined as a structure that can retain verbal information for very short periods of time (Baddeley, 2003; Montgomery, 2000). This component, which was called the "articulation loop" in the first few years of the model's introduction, was subsequently named the "phonological loop" (Montgomery et al., 2010; Thomason et al., 2009; ZhenZhu, Ming, & XiaoLin, 2008). The visual-spatial sketchpad component of working memory is responsible for the temporary storage and manipulation of visual, spatial and kinesthetic information (Baddeley, 2003). This area also plays a key role in the formation and manipulation of mental images (Lanfranchi, Jerman, & Vianello, 2009). The central executive component of the model provides control, regulation and monitoring of the activities taking place in the phonological loop and visual-spatial space. The central executive is responsible for functions such as initiating processing, directing attention, choosing a strategy, managing sub-systems and the resources allocated to them (Öztürk, Elmastaş Dikeç, & Tekok Kılıç, 2009). The "episodic buffer" (Irak, 2009) component, added to the model as the fourth mechanism by Baddeley (2000, 2003), is a system with limited capacity, responsible for combining information from various sources. This system, controlled by the central executive, provides access to consciously stored information, and the manipulation and adaptation of information when necessary (Baddeley, 2003).

Working memory, which is stated to be closely related to many academic skills, keeps the visually presented letters or words in the short-term memory (processing words visually), obtains necessary information from the long-term memory (matching with phonological, orthographic and semantic representations in the long-term memory) and is involved in the reading process by integrating information sources (combining representations with context to the comprehension of text) (Peng et al., 2018; van den Broek, Mouw, & Kraal, 2016). In the literature, studies indicate that working memory is effective at different levels in different periods, including the acquisition of reading and writing, from kindergarten through to the later years in primary school (Alloway & Copello, 2013;

Alloway & Gregory, 2013; Demirtaş & Ergül, 2019). The results of the study, conducted by Swanson and Beebe-Frankenberger (2004) also show that working memory predicts the reading success of children with typical development at a higher level, compared to skills such as phonological awareness, which is closely related to reading skills in the literature. Savage, Lavers, and Pillay (2007) examined the possible relationship between reading and working memory in their review. They suggested that working memory plays a greater role in the acquisition and development of more advanced skills, such as reading comprehension, compared to decoding but it remains unclear to what extent reading is affected by the components of working memory (verbal and visual component). However, in relatively recent studies, the relationship between different dimensions of reading have been examined, such as fluent reading and comprehension and the components of working memory, as well as the possible role of the structural features of the language, used in the interaction of reading and working memory (Dolean, Lervåg, Visu-Petra, & Melby-Lervåg, 2021; Nevo & Breznitz, 2011; Peng et al., 2018). In this context, it is important to consider the interaction between different components of reading fluency, reading comprehension and working memory.

Reading Fluency, Reading Comprehension and Working Memory

Reading fluency, which is a complex skill, requires the simultaneous and successful use of more than one cognitive and linguistic process (Fuchs, Fuchs, Hosp, & Jenkin, 2001). Fluent reading is generally defined as the ability to read a text quickly, accurately and with suitable expression (Kuhn, Schwanenflugel, & Meisinger, 2010; Pikulski & Chard, 2005) and includes decoding a word and converting the decoded word into spoken language. Therefore, automatic analysis is of great importance for fluency (Kuhn et al., 2010; Pikulski & Chard, 2005). There are studies in the literature that associate vocabulary-level skills such as decoding and vocabulary with general cognitive competencies (Rapp, van den Broek, McMaster, Kendeou, & Espin, 2007). In certain studies, it has been found that the acquisition of orthographic knowledge has a regulatory effect on the processing of the syllable or phoneme structure of words, and this result has been interpreted as fluent reading and is associated with working memory (Petersson, Silva, Castro-Caldas, Ingvar, & Reis, 2007; Silva, Faísca, Ingvar, Petersson, & Reis, 2012).

In studies examining the relationship between working memory and reading fluency, it has been stated that the verbal component of working memory, in particular, can affect both reading fluency and reading comprehension. In the research, it is stated that students with better verbal working memory can convert letters into sounds more accurately, can store these sounds in their memory and can blend and segment these sounds during decoding (Joubert et al., 2004; Purpura, Schmitt, & Ganley, 2017). Studies examining the relationships between working memory and word reading suggest that visual working memory is not related to word reading (Messer, Henry, & Nash, 2016; Oakhill, Yuill, & Garnham, 2011). However, it is stated that children with reading difficulties perform poorly in both verbal and visual working memory compared to successful readers (Reiter, Tucha, & Lange, 2005). In addition, it is stated that students who perform better in terms of verbal working memory can keep longer texts in their memory in situations that require higher-level skills such as summarizing and linguistic understanding, and the results indicate the indirect interaction between reading fluency, working memory and reading comprehension (Perfetti & Stafura, 2014; Silva & Cain, 2015; Spencer & Wagner, 2018). In addition, it has been emphasized in many studies in the literature that decoding and reading comprehension skills in particular overlap at certain points in terms of cognitive relations, but these relations may change during the developmental process (Cain, Oakhill, & Bryant, 2004; Catts, Adlof, & Weismer, 2006; Hoover & Gough, 1990; Oakhill & Cain, 2012; Oakhill, Cain, & Bryant, 2003). Moreover, studies have suggested that working memory may function differently during reading fluency and reading comprehension (Catts et al., 2006; Christopher et al., 2012; Cutting, Materek, Cole, Levine, & Mahone, 2009; Davidson, Kaushanskaya, & Weismer, 2018; Locascio, Mahone, Eason, & Cutting, 2010; Palladino & Ferrari, 2013).

Individuals who perform working memory tasks should remember some of the items related to the task while completing the tasks related to the task, and ignoring or blocking out other items (Cain et al., 2004). Reading comprehension also requires focusing on certain elements in the text, processing the text, comprehending the meaning of the text and integrating the existing information with the new information (Perfetti, Landi, & Oakhill, 2005); it is stated that reading comprehension in these aspects is mainly related to working memory (Nation, Adams, Bowyer- Crane, & Snowling, 1999; Palladino, Cornoldi, De Beni, & Pazzaglia, 2001). Indeed, in longitudinal studies, it has been shown that working memory performance uniquely predicts the development of reading comprehension skills (Cain et al., 2004; Lee Swanson, 2011; Seigneuric & Ehrlich, 2005).

In the literature, it is suggested that the reading comprehension process benefits from many different basic literacy skills and cognitive skills, even when word reading skills are controlled (Cain et al., 2004); the reading comprehension process shows stronger relationships with working memory compared to other reading skills (Daneman & Merikle, 1996; Savage et al., 2007). Studies show that working memory plays a critical role in integrating information during the comprehension of text (Swanson & O'Connor, 2009). Both cross-sectional (Carretti, Borella, Cornoldi, & De Beni, 2009; Daneman & Merikle, 1996; Follmer, 2018) and longitudinal studies (Seigneuric & Ehrlich, 2005) have shown that the contribution of working memory to reading comprehension is significant even after decoding and language skills are controlled (Nouwens, Groen, Kleemans, & Verhoeven, 2020; Sesma, Mahone, Levine, Eason, & Cutting, 2009). In addition, it has been shown that the relationship between working memory and reading comprehension differs according to grade levels, revealing a stronger relationship at first grade level (Peng et al., 2018). It is stated that working memory not only contributes directly to reading comprehension, but also indirectly affects reading comprehension through decoding and vocabulary (Cromley & Azevedo, 2007; Peng & Goodrich, 2020). In addition, it is suggested that working memory plays an active role in individual differences in inference and comprehension skills in text reading, and that reading comprehension difficulties and working memory performance are related independently of word recognition difficulties (Oakhill et al., 2003; Swanson, Howard, & Sáez, 2006). In general, individuals with reading difficulties performed poorly in simple and complex verbal working memory tasks (Wang & Gathercole, 2013) and in early studies comparing the visual-spatial memory performance of readers with and without reading difficulties, indicating impairment in the visual working memory tasks of individuals with reading difficulties (Kibby, Marks, Morgan, & Long, 2004; Swanson & Berninger, 1995; Swanson, Ashbaker, & Sachse-Lee, 1996). However, certain studies show that children with reading difficulties may also have impairments in terms of storing and using visual/spatial information (Gathercole, Alloway, Willis, & Adams, 2006; Swanson et al., 1996; Swanson, Zheng, & Jerman, 2009). There are also studies suggesting that the main variable that helps explain reading comprehension performance is the verbal component of working memory, in other words, verbal working memory beyond the contribution of basic language skills, such as word reading (Carretti et al., 2009; Savage, Cornish, Manly, & Hollis, 2006). Studies show that readers with weaker reading comprehension skills have difficulties in processing information specific to the verbal component of working memory (Carretti et al., 2009). In addition, it has been suggested that children with reading difficulties and reading comprehension problems have difficulties in reading comprehension, as a result of differences in phonological processing, including a low storage capacity in their working memory (Van der Leij & Morfidi, 2006).

While all these findings reveal the relationships between working memory, reading fluency and reading comprehension, it is noteworthy that most of the research on the subject was conducted in opaque orthographies with low letter-sound consistency. However, it is stated that the structural features of the language used by the reader and the letter-sound consistency in the written language, may play a role in the acquisition of reading and reading comprehension, especially in studies focusing on the acquisition of reading (Ziegler & Goswami, 2005). It is stated that this may differ in orthographies (Dolean et al., 2021; Masoura, Gogou, & Gathercole, 2020). From this point of view, this study aims to examine the verbal and visual working memory performances of Turkish-speaking children in the kindergarten, predicting their reading fluency and reading comprehension performances in the first and second grades, longitudinally. In line with this objective, the study sought to answer the following questions:

1. What is the predictive power of verbal and visual working memory performances at kindergarten level on reading fluency and reading comprehension performances in the fall and spring semesters of the first grade?
2. What is the predictive power of the verbal and visual working memory performances at kindergarten level on the reading fluency and reading comprehension performances of the second graders in the fall and spring semesters?

Method

The research was carried out within the scope of a larger-scale project to determine the developmental profile of the language, early literacy and cognitive skills of Turkish-speaking children attending kindergarten. The study also examined the predictive power of these skills in relation to reading skills, and the predictive correlational research design method was used.

Participants

The research was conducted in a total of 45 schools, randomly selected from each stratum and representing the lower-middle and upper socioeconomic levels in the province of Ankara. Two randomly selected branches in each school and six randomly selected children from each branch participated in the study. Another child from the same class was selected randomly and included in the study, instead of an individual who did not meet the criteria for inclusion in the study. Although the kindergarten started with a total of 540 children in the fall, the study was completed with 450 children, due to the loss of participants resulting from school changes, absenteeism, moving house and withdrawal from the study. It was determined that 126 (28%) of the participants were in the low socioeconomic level, 194 (43.1%) in the middle socioeconomic level and 130 (28.9%) in the upper socioeconomic level. The participants, who were aged five (M= 66.29 months, SD= 3.91) at the beginning of the study, consisted of children whose native language was Turkish and whose non-verbal cognitive abilities were considered appropriate for their age by applying the TONI-3 Non-Verbal Intelligence Test. The participants did not have any diagnosis of cognitive and/or sensory disabilities. A total of 450 children (224 girls, 250 boys), who met these criteria, were included in the study.

Measures

In the study, the SES Index Parent Information Form was used to determine the socioeconomic characteristics of the participants; the measurements of the working memory performance in the kindergarten were recorded using the WMS, and the measurements of the reading fluency and reading comprehension performances in the first and second grades were made using the LAB. The scores obtained from the TONI-3 Non-Verbal Intelligence Test were taken as the basis for the determination of non-verbal cognitive competencies.

SES Index Parent Information Form (Ergül & Demir, 2017): the form was used to determine the socioeconomic levels of the participants' families and includes 23 SES variables (parents' educational status, occupational status, homeownership, book ownership and participation in cultural events). The form was created by collecting data from the parents of a total of 2411 children from kindergarten to fourth grade, with five SED levels defined as low, middle-low, middle, middle-upper and upper. As a result of the analysis, the five-factor structure of the form, which explains 57% of the variance for the SED index, was defined and confirmed.

Working Memory Scale (WMS): this was developed by Ergül et al. (2018) to measure the working memory performance of children attending kindergarten, first, second, third and fourth grades. The scale consists of two dimensions: verbal and visual memory. Digit Recall, Word Recall, and Nonsense Word Recall subtests evaluated verbal short-term memory in the verbal memory dimension; Reverse Digit Recall and First Word Recall subtests were used to evaluate verbal working memory. In the visual memory dimension, there are Pattern Matrix and Block Recall subtests to assess visual short-term memory and Differential Selection and Spatial Discrimination subtests to assess visual working memory. Each subtest consists of items containing an increasing number of sequences and two trials in each item. Each subtest also includes two to three sample exercises in order that the child understands the task. During the implementation of the subtests, the sequences in each item were presented to the child in order, and if the child was successful in at least one of the trials in each item, the next item was passed. If both attempts were unsuccessful, that subtest was terminated and the next subtest was started. One point was given for each sequence that the children repeated/marked in the correct order. As a result of the validity study of the scale, the factor load values of the scale items varied between .49 and .93, the item-total correlation values were between .21 and .60, the item discrimination of the other items at the subscales changed between .32 and .82 and the criterion validity for the subscales was found to be between 62 and .94. As a result of the reliability analysis of the scale, it was found that the internal consistency coefficient of the subscales was between .74 and .99 and the test-retest correlation values were between .59 and .83. The standard scores for verbal memory, visual memory and working memory were also obtained from the scale, and the children's performances were graded as very low, low, medium, high and very high according to these scores.

TONI-3 Non-Verbal Intelligence Test: TONI-3 was developed by Brown, Sherbenou, andJohnsen (1997) to measure the non-verbal cognitive competence of individuals aged 6-89 years, and each form of the test, which includes two parallel forms, A and B, is ranked according to the level of difficulty. There are 45 items in each. Each form of the test contains six possible answer options, and the dichotomous scoring is conducted by giving “1” point for each correct answer and “0” points for each incorrect answer. After three incorrect answers within five consecutive items, the application of the test was terminated; the test takes approximately 15-20 minutes (Bildiren & Korkmaz, 2018). It was found that the test had Turkish validity, reliability and standardization, and was between .90-93 for the B form. It was found that the parallel form reliability coefficient was .80, the test-retest reliability coefficient was .65 for form A and .70 for form B. The criterion validity study of the test was performed with the Raven Standard Progressive Matrices Test, and it was determined that the correlation between the two test scores was .79 for form A and .82 for form B. The other criterion-related validity correlations were 0.52 between academic achievement and the TONI-3 A form, 0.49 for the B form; the subtests of the Wechsler Intelligence Scale for Children were 0.31 between Piece Assembling and the TONI-3 A form, 0.38 for the B form and was 0.47 between Pattern with Cubes and the TONI-3 A form, 0.51 for the B form; It was stated that the similarities were 0.47 for the TONI-3 A form and 0.57 for the B form (Korkmaz, Bildiren, Demiral, & Çulha, 2018). Within the scope of this research, children's non-verbal cognitive competencies were evaluated using form B.

Literacy Assessment Battery (LAB): this was developed by Ergül, Ökçün-Akçamuş, Akoğlu, Kılıç-Tülü, and Demir (2021) to assess the reading, reading comprehension and writing skills of children from first grade to fourth grade. The LAB aims to examine different aspects of reading, comprehension and writing. The LAB includes four tests for reading, three tests for comprehension and three tests for writing. The tests, created by considering the structural features of Turkish, have A and B forms parallel to one other and each test is administered individually. The analysis results for determining validity and reliability showed that the LAB consists of three sub-dimensions: reading, comprehension and writing, and the paths between all the subtests of the battery and these sub-dimensions are significant. It was determined that the fit indexes of the three sub-dimensions, consisting of reading, writing and comprehension, were high. As proof of validity in the sense of discrimination of the test, it was found that there were significant differences at the level of .001 between the lower and upper groups in all tests, and the effect sizes (eta-square) for significant differences, with values between .53 and .71, indicated high discriminant validity. Regarding criterion validity, the composite scores obtained from the LAB were shown to be significantly correlated with phonological awareness, working memory, rapid naming, verbal language and vocabulary, between .10-.44 and $p<.01$. Cronbach's alpha internal consistency coefficients of the LAB were between .67 and .85; the test-retest correlation coefficients were found to be between .86 and .96, and the correlation coefficients for the equivalence of the A and B forms of all tests were found to be between .82 and .96. At each grade level and term, the cut-off points and ranges for evaluation were determined, and the "very low; low: medium; high; very high" evaluations can be made. In this study, Word Recognition, Word Decoding, Phonetic Analysis Tests and Passage Reading Fluency Tests were used to assess reading skills, and the Cloze Test, Semantic Processing Test and Passage Comprehension Test were used to assess reading comprehension skills.

Reading Tests

Word Recognition *Test:* in the test developed to determine reading accuracy and fluency, there is a word list consisting of a total of 100 words, including five monosyllables, 15 two-syllables, 30 three-syllables, 30 four-syllables, 15 five-syllables and five six-syllable words. The test, which has two parallel forms, A and B, was used in the evaluation of pupils in the first and second grades, and the TTKB Vertical Basic Abece Font and the 18-point form of the words were used. For the child to understand the task, a sample application was made with a shortlist of six words before the application. In the time-based test, the number of correct words read in one minute was determined as the performance score.

Word Decoding Test: the test used to determine fluency in phonological decoding is a total of 60 nonsense words consisting of five monosyllables, 10 two-syllables, 15 three-syllables, 15 four-syllables, 10 five-syllables and five six-syllable words. In the evaluations of the test, which has two parallel forms, A and B, with the first and second grades, the TTKB Vertical Basic Abece font and the 18-point form of the words were used. In the evaluations made with the third and fourth grades, the 14-point form of the same font was used. In the time-based test, the number of correct words read in one minute was determined as the performance score.

Phonetic Analysis Test: in a test that evaluates the ability to distinguish phonemes in words and matching letter-sound, children were asked to distinguish the first sound of the words spoken to them and show the letter corresponding to this sound among three letters on a card, also shown to them. The test, which has two parallel forms, A and B, each consisting of 53 words, was applied on a timely basis and the number of correctly displayed letters in one minute was determined as the performance score.

Passage Reading Fluency Test: in the test used to determine text reading fluency, the correct number of words that children read in one minute in narrative and informative texts at grade level was determined. In the test, which has parallel A and B forms, a total of four texts, two narrative and two informative, were used for each grade level (1-4.). In the evaluations of pupils in the first and second grades of the test, in which the font size differs according to the grade level, the TTKB Vertical Basic Abece font and the 18-point form of the texts were used. In the evaluations of pupils in the third and fourth grades, the 14-point form of the same font was used. In the time-based test, the average of the correct number of words read in one minute in the narrative and informative text was determined as the performance score. Within the scope of this research, two texts with narrative and informative text structure and independent readability levels, suitable for first- and second-grade levels were used.

Reading Comprehension Tests

Cloze Test: in this test, developed to evaluate their reading comprehension skills, children were expected to determine a blank word in a sentence based on semantic clues. The number of words in the sentences of the test ranged from two to 11, and the sentences were ordered from easy to difficult depending on complexity. The test consisted of a total of 32 items that required the word to be left blank in the sentence, to be chosen from among three options; the test had two parallel forms (A and B) with similar complexity and semantic features. The TTKB Vertical Basic Abece font and its 18-point form were used in the evaluations of the pupils in the first and second grades of the test, in which the font size differs according to the grade level. In the evaluations of pupils in the third and fourth grades, the 14-point form of the same font was used. The test score was calculated based on the number of words correctly selected to insert into the blanks within two minutes.

Semantic Processing Test: in this test, which requires children to decide whether the sentences they read are semantically correct or not, the children were tasked with distinguishing between 45 sentences. After reading the sentences as quickly and carefully as possible, the children were asked to indicate their answers by marking the appropriate facial expressions (happy and sad facial expressions) opposite the sentences. In the time-based test, the performance score was determined according to the number of correctly defined items in 90 seconds.

Passage Comprehension Test: the Text Reading Test was used in the test, which aims to evaluate children's reading comprehension skills by using texts. Three different criteria were obtained from the test, which has no time limit, namely knowledge, inference and total score, and marks are awarded according to the number of correct answers to questions relating to the text. Within the scope of this research, the total number of correct answers to the questions in the narrative text among first graders in the fall semester and the total score of text comprehension in the other semesters were used.

Data Collection

Ethics committee permission to conduct the study was granted and written consent was obtained from the families of the children participating in the research and evaluation processes. It is essential that families and children volunteer to participate in the research, and their right to withdraw from the study is reserved.

Working memory measurements made within the scope of the research were carried out in the spring semester in the kindergarten. The reading fluency and reading comprehension performances of children whose working memory was measured, were evaluated in the fall and spring semesters of the first grade and in the fall and spring semesters of the second grade in the primary schools they attended. Thus, children who were assessed in terms of working memory in the kindergarten were followed longitudinally in terms of reading fluency and reading comprehension skills at four points during the first and second grades. The measurement procedures carried out in the research were conducted by graduate and doctorate students who were trained by the researchers, who were qualified to apply the measurement tools used in this research and who took part in the project as scholarship holders. All measurements were made individually with each participant, in a quiet room within the school and across two sessions. During the application of the tools used, the order of application of the tools was changed to control the order effect. All assessments were made in the fall semester in the last two weeks

of November and in December; the assessments made in the spring semester took place in the last two weeks of April and in May.

Statistical Analysis

Data analyses were conducted using working memory measurements in the spring term in the kindergarten, and the measurement results of reading fluency and reading comprehension skills were taken longitudinally throughout the four terms. Before the analysis, the data were analyzed based on univariate and multivariate normality assumptions and the Skewness and Kurtosis values were found to be in the range of ± 1. To examine the prediction of reading fluency and reading comprehension skills, exhibited in the fall and spring semesters of the first and second grades, descriptive statistics were examined for all variables in the first stage and analyses were made as to whether there was autocorrelation and multicollinearity between the variables. After determining that there was no autocorrelation between the data, the predictive status of working memory measurements on reading fluency and reading comprehension skills was determined using the structural equation model.

Results

A study was carried out to determine the level of predicting the reading and reading comprehension performance in terms of working memory of children in the first and second grades, who had been evaluated in the kindergarten; the descriptive statistics regarding the variables covered in the study were initially examined. While the descriptive statistics relating to the scores obtained from the WMS are shown in Table 1, the descriptive statistics on the reading fluency and reading comprehension scores in the first and second grades, according to the periods, are shown in Table 2.

Table 1. Descriptive Statistics of Scores from the Working Memory Scale

	N	**Mean**	**SD**	**Min.**	**Max.**
Working Memory	450	14,19	5,34	2,00	35,00
Verbal Working Memory	450	11,90	4,20	1,00	24,00
Visual Working Memory	450	2,29	2,13	,00	12,00

Table 2. Descriptive Statistics on First and Second Grade Reading Fluency and Reading Comprehension Scores

		First Grade				**Second Grade**			
		Fall semester (n=368)		Spring semester (n=368)		Fall semester (n=368)		Spring semester (n=368)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Reading	Word Recognition	15,09	9,98	37,41	11,54	45,66	12,90	52,42	13,58
	Word Decoding	10,89	6,97	21,70	6,76	25,51	6,67	27,89	6,92
	Phonetic Analysis	15,81	4,55	19,80	4,18	23,63	4,46	25,17	4,57
	Passage Reading Fluency	15,67	13,23	45,53	18,52	61,55	20,69	74,11	21,81
Reading	Cloze Test	2,57	2,20	7,26	2,61	9,97	3,12	11,34	3,41
Comprehension	Semantic Processing	5,78	4,10	12,89	3,93	16,21	4,04	18,91	4,66
	Passage Comprehension	2,78	2,57	4,68	1,57	5,89	1,46	6,12	1,53

The descriptive statistics on working memory and its components, shown in Table 1, indicated that the averages obtained by the children from the WMS were in accordance with the average performance of the kindergarten children within the framework defined by the scale. When the descriptive statistics on reading fluency and reading comprehension skills in the first and second grades, summarized in Table 2, were analyzed, it was noted that the averages for each variable increased between the first grade and the second grade, and between the fall semester and the spring semester at each grade level.

Within the scope of the study, a structural equation model was used to determine the predictive value of working memory measurements on reading fluency and reading comprehension skills in the fall and spring semesters of the first and second grades. Analyses were conducted separately for each period and are presented in order below.

Prediction of Verbal and Visual Working Memory Performances in the Kindergarten in Relation to Reading Fluency and Reading Comprehension Performances in the Fall Semester of the First Grade

The scores on verbal and visual working memory measurements in the kindergarten were predicted, and the variables on reading fluency and reading success in the fall semester of the first grade were tested using the structural equation model. The standardized path coefficients obtained are summarized in Figure 1.

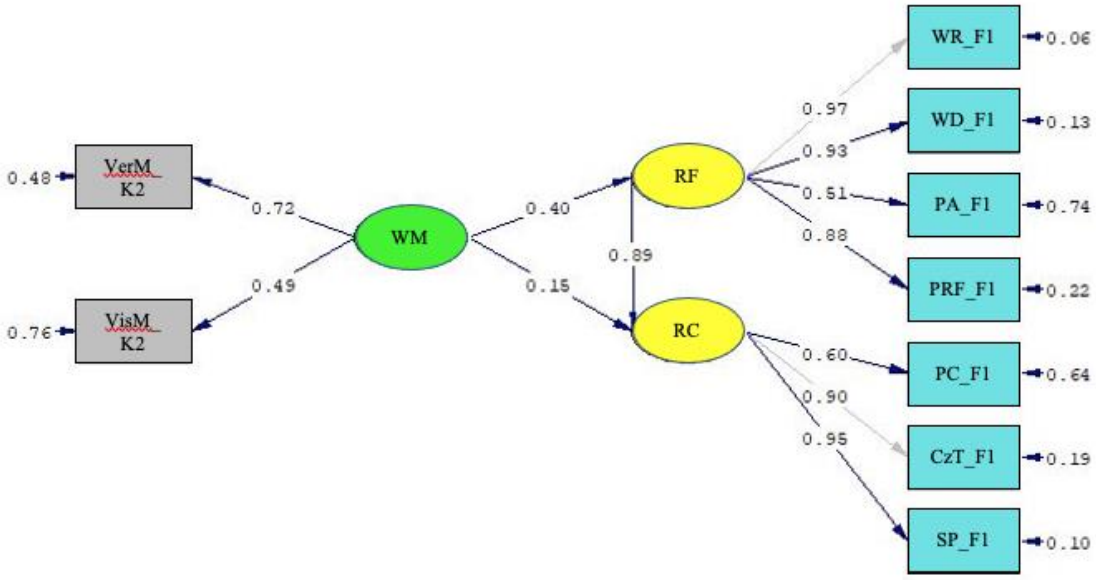

Figure 1. Relationships between the verbal and visual working memory performance in the kindergarten and reading fluency and reading comprehension performance in the fall semester of the first grade (Model 1 standardized path coefficients)

Model 1 shown in Figure 1 is statistically significant (χ2=77.41, sd=24, and p<0.01) and provides a good level of model-data fit (χ2/sd=3.23, RMSEA=.070, NFI=.98, NNFI= .98, CFI=.99, IFI=.99, GFI=.96, SRMR=.042). In Model 1, the paths between working memory and reading fluency (t = 6.20 and p<.05) and reading comprehension (t = 4.33 and p<.05) were significant, as well as the path between reading fluency and reading comprehension (t = 4.33 and p<.05). = 14.21 and p<.05) were found to be significant. According to Model 1, working memory performance in the kindergarten is a positive predictor of reading fluency and reading comprehension in the fall semester of the first grade. In addition, reading fluency in the first-grade fall semester significantly predicts reading comprehension performance in the same semester. Among the working memory components in the kindergarten, the verbal component (syk=.72) made the greatest contribution to reading fluency and reading comprehension performance in the first-grade fall semester. The contribution of working memory to reading fluency is higher than its contribution to reading comprehension. A one-unit increase in working memory performance corresponds to a .40-unit increase in reading fluency and a .15-unit increase in reading comprehension. A one-unit increase in reading fluency in the fall semester of the first grade corresponds to an increase of .89 units in reading comprehension during the same period.

The Prediction of Verbal and Visual Working Memory Performances in the Kindergarten in Relation to Reading Fluency and Reading Comprehension Performance in the Spring Term of the First Grade

The scores on the verbal and visual working memory measurements in the kindergarten were predicted, and the variables regarding reading fluency and reading success in the spring semester of the first grade were tested using the structural equation model. The obtained standardized path coefficients are summarized in Figure 2.

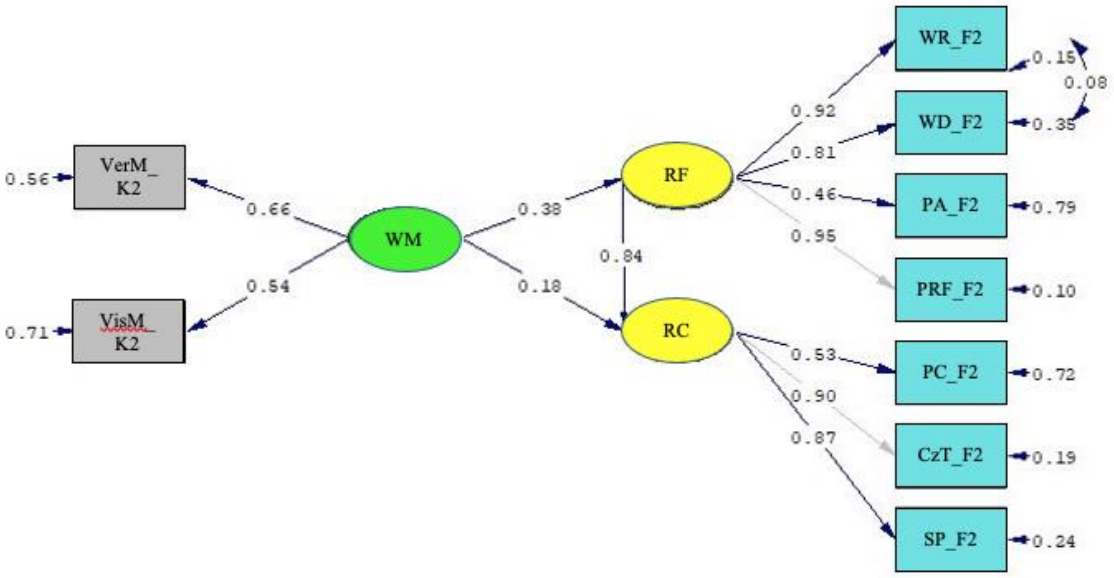

Figure 2. The relationships between verbal and visual working memory performance in the kindergarten and first-grade reading fluency and reading comprehension performance in the spring term (Model 2 standardized path coefficients)

As a result of the analysis, Model 2 was statistically significant (χ2=91.46, sd=23 and p<0.01) and provided an acceptable level of model-data fit (χ2/sd=3.98, RMSEA=.081, NFI=.98, NNFI) =.97, CFI=.98, IFI=.98, GFI=.96, SRMR=.046). In Model 2, the pathways between working memory and reading fluency (t = 5.77 and p<.05) and reading comprehension (t = 4.06 and p<.05) and between reading fluency and reading comprehension (t = 11.37 and p<.05). 05) are significant. According to Model 2, working memory performance in the kindergarten is a positive predictor of reading fluency and reading comprehension performance in the spring semester of the first grade. Reading fluency in the spring semester of the first grade significantly predicts the reading comprehension performance in the same semester. Among the working memory components in the kindergarten, the verbal component (syk=.66) made the highest contribution to reading fluency and reading comprehension performance in the spring term of the first grade. Similar to the findings in Model 1, the contribution of working memory to reading fluency is higher than its contribution to reading comprehension. A one-unit increase in working memory corresponds to an increase of .38 units in reading fluency and .18 units in reading comprehension. A one-unit increase in reading fluency in the spring semester of the first grade corresponds to an increase of .84 units in reading comprehension in the same semester.

The Prediction of Verbal and Visual Working Memory Performances in the Kindergarten with Regard to Reading Fluency and Reading Comprehension Performance in the Fall Semester of the Second Grade

The scores of the Phonetic Analysis Test, which is one of the reading tests, were excluded from the model, as the t value was not significant in the analyses carried out in the sophomore fall semester, and the analyses were conducted with the newly created model. Accordingly, in the new model, working memory and verbal and visual components were used as predictor variables, and other variables related to reading fluency and reading comprehension, excluding phonetic analysis, were used as predicted variables. The obtained standardized path coefficients are summarized in Figure 3.

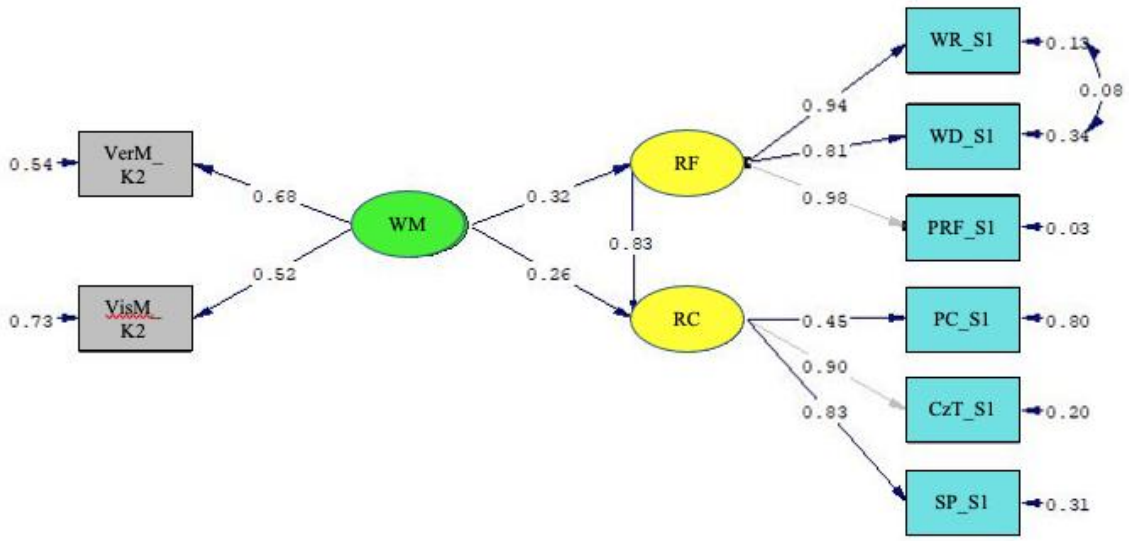

Figure 3. Relationships between verbal and visual working memory performance in the kindergarten and second-grade reading fluency and reading comprehension performance in the fall term (Model 3 standardized path coefficients)

The analyses carried out in Model 3 were statistically significant ($\chi 2$=44.49, sd=16, and p<0.01) and provided a good level of model-data fit ($\chi 2$/sd=2.78, RMSEA=.063, NFI=.99, NNFI=. .98, CFI=.99, IFI=.99, GFI=.98, SRMR=.037). In Model 3, the paths between working memory and reading fluency (t = 5.02 and p<.05) and reading comprehension (t = 5.49 and p<.05) and between reading fluency and reading comprehension (t = 9.59 and p<.05). 05) were found to be significant. According to Model 3, working memory performance in the kindergarten is a positive predictor for reading fluency and reading comprehension performance in the fall term of the second grade. In addition, reading fluency in the fall semester of the second grade significantly predicts the reading comprehension performance in the same semester. Among the working memory components in the kindergarten, the verbal component (syk=.68) made the highest contribution to reading fluency and reading comprehension performance in the fall semester of the second grade. The contribution of working memory to reading fluency and reading comprehension is close. A one-unit increase in working memory corresponds to a .32-unit increase in reading fluency and a .26-unit increase in reading comprehension. A one-unit increase in reading fluency in the sophomore fall semester corresponds to an increase of .83 units in reading comprehension in the same semester.

The Prediction of Verbal and Visual Working Memory Performances in the Kindergarten in Relation to Reading Fluency and Reading Comprehension Performance in the Spring Term of the Second Grade

In the analyses for the spring semester of the second year, as in the fall semester, the phonetic analysis was excluded from the model and the remaining analysis was carried out, since the t value was not significant. Accordingly, in the model, scores related to verbal and visual working memory measurements in the kindergarten were used as predictive variables, while variables related to reading fluency and reading success in the spring semester of the second grade were used as predicted variables. The new model created was tested using the structural equation model. The standardized path coefficients obtained are summarized in Figure 4.

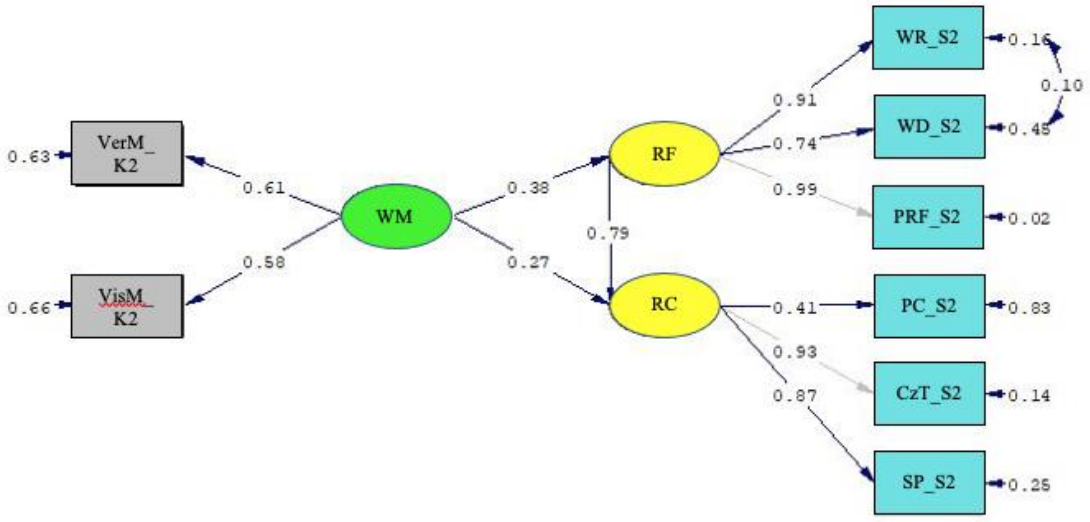

Figure 4. Relationships between verbal and visual working memory performance with regard to reading fluency and reading comprehension performance in the kindergarten and second grade during the spring term (Model 4 standardized path coefficients)

The analyses conducted by Model 4 were statistically significant ($\chi 2$=51.80, sd=16, and p<0.01) and provided a good level of model-data fit ($\chi 2$/sd=3.24, RMSEA=.071, NFI=.98, NNFI=. 98, CFI=.99, IFI=.99, GFI=.97, SRMR=.036). In Model 4, the pathways between working memory and reading fluency (t = 5.92 and p<.05) and reading comprehension (t = 6.53 and p<.05) were found to be significant. According to Model 4, working memory performance in the kindergarten is a positive predictor of reading fluency and reading comprehension performance in the spring semester of the second grade. Reading fluency in the spring semester of the second grade significantly predicts the reading comprehension performance in the same semester. Among the working memory components in the kindergarten, the verbal component (syk=.61) made the greatest contribution to reading fluency and reading comprehension performance in the spring term of the second grade. The contribution of working memory to reading fluency and reading comprehension is close. A one-unit increase in kindergarten working memory performance corresponds to a .38-unit increase in reading fluency and a .27-unit increase in reading comprehension. A one-unit increase in reading fluency in the sophomore spring semester corresponds to a .79-unit increase in reading comprehension in the same semester.

Discussion, Conclusion and Suggestions

The results obtained from the study revealed that the reading fluency and reading comprehension performances of the longitudinally assessed participants increased from the first grade to the second grade, and from the fall semester to the spring semester at each grade level. In the study, it was also found that the verbal and visual working memory scores in the kindergarten contributed to the reading fluency and reading comprehension success in the fall and spring semesters of the first and second grades at different levels.

The findings of the study show that working memory measured in the kindergarten is a predictor of reading fluency and reading comprehension in the first and second grades and that the contribution of working memory to reading fluency is greater than reading comprehension. In addition, it is noteworthy that the contribution rates of working memory to reading fluency and reading comprehension performances are generally close to one other in the second grade compared to the first grade. Although there are limited studies in the literature indicating a relatively strong relationship between reading fluency and working memory (Johann, Könen, & Karbach, 2020), it has been stated that the relationship between reading fluency and working memory may be affected by grade level, and this is consistent with the "simple view of the reading model". This is explained by gradually gaining competence in analysis, which is one of the basic skills for fluent reading. Decoding is often measured using real words and nonsense words in the literature, and it is associated with working memory by stating that decoding real words or nonsense words mostly requires the letters to be converted into sounds in order, and stored simultaneously to create meaning (Peng et al., 2018). In the study, word recognition, word decoding (reading nonsense words), phonetic analysis and passage reading tests all require the use of decoding, suggesting that decoding plays a role in the predictive relationship between working memory and reading fluency. In addition, there are studies in the literature suggesting that the relationship between working memory and reading comprehension is stronger in the early grades and that working memory not only contributes directly to reading comprehension but also indirectly affects reading comprehension through decoding and vocabulary (Cromley & Azevedo, 2007). The research was carried out with the participants at first and second-grade levels, therefore, at the beginning of their reading acquisition. In the literature, the developmental perspective on reading acquisition (Chall, 2013) deals with the process of becoming a successful reader within a framework that starts at kindergarten level and progresses at different grade levels. From this point of view, students acquire skills such as letter knowledge, phoneme awareness and sound-symbol matching, and begin to develop the decoding skills necessary for basic reading skills in kindergarten and first grade. At the end of the second grade, these basic reading skills are reinforced so that the analysis becomes automatic, and readers who can analyze automatically with an appropriate speed can allocate more space cognitively to reading comprehension tasks (Florit & Cain, 2011). From this point of view, researchers argue that especially the verbal component of working memory contributes to different levels at different stages of reading, and that the role of verbal working memory in reading, from kindergarten to first grade, can be better explained by its contribution to decoding, indicating that it can be effective. In addition, it is emphasized in the literature that the difference between students' processing speed and their native language level are also important determinants (Zhang & Joshi, 2020). Considering the contribution of reading fluency to reading comprehension, the results obtained in the study suggest the possible effects of basic reading skills in terms of contributing to reading fluency, as well as working memory. However, it is worth noting that studies on the subject are mostly conducted in languages with an opaque orthography. For this reason, there is a need for studies that deal with the subject in the context of the structural features of Turkish, to reveal the possible variables that are thought to have an indirect effect on reading comprehension.

In the study, verbal memory made the highest contribution to reading fluency and reading comprehension performance in the first and second grade by comparison with visual memory. Moreover, many studies present the contributions of both verbal and visual-spatial working memory to reading fluency and reading comprehension (Cromley & Azevedo, 2007; Goff, Pratt, & Ong, 2005). Findings show that verbal memory especially predicts reading comprehension beyond reading, fluency and vocabulary (Cain et al., 2004; Cutting et al., 2009; Oakhill et al., 2011; Sesma et al., 2009). Although there are limited longitudinal studies on the subject, research by Alloway and Alloway (2010) found that verbal working memory measured in the kindergarten predicted the reading composite score six years later, after controlling for intelligence scores and short-term memory performance. Similarly, in the study conducted by Morgan, Farkas, Hillemeier, Pun, and Maczuga (2019), it was observed that the verbal working memory score, measured in the kindergarten, continued to contribute to reading success in the second grade after demographic variables and other academic skills were controlled. Nevo and Bar-Kochva (2015) also found that verbal working memory performance in the kindergarten predicted decoding and reading comprehension performance in the first, second and fifth grades, after controlling for intelligence scores.

In this study, when the contribution levels of verbal and visual working memory are analyzed according to the periods, it is noteworthy that the contribution of verbal working memory decreases somewhat, while the contribution of visual working memory increases as each grade progresses, from the fall term to the spring term. In a study conducted by Silva et al. (2012), it is argued that formal education and literacy education offers a processing strategy based on phonological aspects rather than visual, therefore, verbal working memory mediates the processing of visual-spatial information. In addition, although many studies are suggesting that reading comprehension in particular is related to verbal working memory, some researchers state that this relationship should be handled carefully, due to the linguistic nature of the tasks used in the assessment of working memory (Berninger, Abbott, Cook, & Nag, 2016; Davidson et al., 2018; Oakhill et al., 2011; Seigneuric & Ehrlich, 2005; Swanson & Berninger, 1995). On the other hand, it seems understandable that visual working memory contributes more to the reading process, especially in languages with a transparent orthography such as Turkish, since children learn to read in a shorter time and then develop their orthographic reading skills (Babayiğit & Stainthorp, 2011; Öney & Durgunoğlu, 1997). On the other hand, there is a need for studies that examine the effects of verbal and visual working memory on reading processes in transparent orthographies, by controlling the possible effects of other variables.

In the study, both reading comprehension and reading fluency were associated with verbal memory at a higher level. A study by Nevo and Breznitz (2011) among children who speak Hebrew, a language with an alphabetic orthography, aimed to determine the predictive power of working memory components for reading success six years later. In this study, phonological (verbal) memory was found to be the most powerful predictor of decoding, reading time and reading comprehension performance among all working memory components, including visual working memory. In addition, the difference between the predictive power of working memory components on variables related to reading success, is explained by the existence of different mechanisms, each of which is specific to the working memory component used. In a study conducted by Johann et al. (2020) to determine the individual contributions of working memory, inhibition, cognitive flexibility and fluent intelligence to reading, it was suggested that reading comprehension and reading speed may be related to different cognitive functions. In this context, conducting studies examining the predictive power of grammatical and cognitive functions such as phonological awareness, rapid naming and attention processes, which can affect reading fluency and reading comprehension in languages with a transparent orthography such as Turkish, will make significant contributions to the literature. The results obtained from the study are important in terms of revealing the longitudinal effects of working memory on reading processes, as well as shedding light on the early identification of children who may be at risk in terms of reading and/or reading

comprehension in the future. The findings of the study indicate that children who are at risk in terms of reading fluency and reading comprehension success, which play an important role in future academic success, can be identified in the early stages by evaluating working memory in the kindergarten, and in this respect, the study has the potential to guide the development of preventive approaches.

In this study, although there was an increase in the reading fluency and reading comprehension performance of the participants from the fall semester of the first grade to the spring semester of the second grade, the results of the research show that reading fluency predicts reading comprehension at both grade levels in the fall and spring semesters. When the predictive power of reading fluency in different periods is examined, it is noteworthy that the contribution of fluency to comprehension gradually decreases as the grade level progresses. The theoretical model widely accepted in the literature, especially in inferences regarding the early development of reading comprehension, is the simple view of reading (SVR) (Gough & Tunmer, 1986; Torppa et al., 2016; Ülper, 2018). According to this model, reading comprehension is a product of decoding skills and language comprehension, and when students learn to decode effectively, they can easily and automatically convert a string of letters into words fluently, and can understand these more easily (Hoover & Gough, 1990; Dolean et al., 2021). The contribution of reading fluency to reading comprehension performance in each period also confirms this view. However, in the literature, it has been observed that word recognition, which is the first stage of fluent reading, is also among the skills associated with reading comprehension. Researchers state that at the beginning of the slow-developing fluent reading process, children spend more time and effort on reading, but as their reading experience increases, they can perform word recognition faster, by processing orthographic information more easily (Stanovich, 1991), so word recognition and speed together form the basis for reading comprehension (Ehri, 1997; Gough & Tunmer, 1986; Hoover & Gough, 1990; Stanovich, 1991). In the study, the increase observed in word decoding (nonsense word reading), word recognition (real word reading), phonetic analysis and passage reading means that at each grade level and during each semester, reading fluency gradually increases and this increase contributes to the increase in reading comprehension performance at the same grade level. While most of the studies in the literature on the subject are carried out in languages with an opaque orthography such as English, there are also findings showing that first-grade reading fluency predicts reading comprehension performance at higher grade levels in German, Greek and Finnish, which are more transparent than English (Florit & Cain, 2011; Kendeou, Papadopoulos, & Kotzapoulou, 2013; Verhoeven & van Leeuwe, 2008). Baştuğ and Akyol (2012) examined the relationship between fluent reading and the reading comprehension skills of Turkish-speaking primary school students between the second and the fifth grade. The results obtained from the research revealed that fluent reading factors, such as correct reading and reading speed, especially prosody, are predictors of reading comprehension skills. In a study conducted by Başaran (2013) to determine the relationship between primary school fourth-grade students' fluent reading status and their reading comprehension, it was found that fluent reading is an indicator of reading comprehension. Although determining the possible contributions of reading fluency tests to reading comprehension performance is not one of the main objectives of the study, it is possible to state that the results obtained are generally compatible with the literature. In addition, the decrease in the contribution of reading fluency to reading comprehension performance as the grade level progresses, suggests that other variables that predict reading comprehension performance in subsequent grades may be more effective. In the literature, it is suggested that the predictive role of reading fluency in languages with a transparent orthography is expected to decrease earlier than in languages with an opaque orthography. This is explained by the fact that relatively early development and automatic analysis disentangle the resources allocated for comprehension (Torppa et al., 2016). In addition, various studies show that reading fluency is related to reading comprehension. It is underlined that fluent reading is necessary but not sufficient for reading comprehension (Arrington, Kulesz, Francis, Fletcher, & Barnes, 2014). It has also been stated that the reading comprehension process benefits from basic literacy skills and various cognitive skills, especially working memory (Cain et al., 2004).

The results obtained from the research are important in that they show that working memory is longitudinally related to reading fluency rather than reading comprehension in Turkish, a language with a transparent orthography, in contrast to the results of studies primarily focused on languages with an opaque orthography. However, this research is limited to examining the predictive power of verbal and visual working memory on reading fluency and reading comprehension from kindergarten to second grade. The results of the study show that the contribution rates of both components of working memory approach one other as the grade level progresses, indicating that the possible effects of visual working memory on reading processes may increase. For this reason, conducting studies examining the possible contributions of both components of working memory to reading processes at later grade levels, will contribute to the understanding of the contribution of cognitive functions to reading processes. Further studies will also help eliminate the question marks regarding the necessity of applying intervention approaches that support working memory.

In the literature, studies examining the relationships between working memory and reading processes to determine whether the relationship between these variables is reciprocal, are still awaiting answers. In the comprehensive meta-analysis study conducted by Peng et al. (2018), a working memory-reading development model was proposed, and it was emphasized that central executive functions should be addressed predominantly in early reading processes, in the context of the multi-component working memory model. According to the proposed model, as reading experience increases, lexical and verbal knowledge are consolidated in the long-term memory and readers benefit more from long-term memory to perform various reading tasks. As basic reading skills develop and reading for understanding begins, working memory resources are used to perform reading tasks, so the relationship between reading and working memory becomes reciprocal. According to the proposed model, working memory primarily affects early reading, and reading gradually shapes the development of verbal working memory. An evaluation of the relationships proposed in this model, especially in languages with a transparent orthography such as Turkish, will contribute to the understanding of the relationships between working memory and reading processes and to the construction of effective intervention approaches.

Acknowledgements

This work was supported by the Scientific and Technological Research Council of Turkey under Grant 215K027.

References

Alloway, T. P., & Alloway, R. G. (2010). Investigating the predictive roles of working memory and IQ in academic attainment. *Journal of Experimental Child Psychology, 106*(1), 20-29.

Alloway, T. P., & Copello, E. (2013). Working memory: The what, the why, and the how?. *The Educational and Developmental Psychologist*, *30*(2), 105-118.

Alloway, T. P., & Gregory, D. (2013). The predictive ability of IQ and working memory scores in literacy in an adult population. *International Journal of Educational Research*, *57*, 51-56.

Arrington, C. N., Kulesz, P. A., Francis, D. J., Fletcher, J. M., & Barnes, M. A. (2014). The contribution of attentional control and working memory to reading comprehension and decoding. *Scientific Studies of Reading*, *18*(5), 325-346.

Babayiğit, S., & Stainthorp, R. (2011). Modeling the relationships between cognitive-linguistic skills and literacy skills: New insights from a transparent orthography. *Journal of Educational Psychology*, *103*(1), 169-189. doi:10.1037/a0021671

Baddeley, A. (2000). The episodic buffer: A new component of working memory?. *Trends in Cognitive Sciences*, *4*(11), 417-423.

Baddeley, A. (2003). Working memory and language: An overview. *Journal of Communication Disorders*, *36*(3), 189-208.

Baddeley, A., & Hitch, G. J. (1976). Verbal reasoning and working memory. *Quarterly Journal of Experimental Psychology, 28*(4), 603-621.

Başaran, M. (2013). Okuduğunu anlamanın bir göstergesi olarak akıcı okuma. *Kuram ve Uygulamada Eğitim Bilimleri*, *13*(4), 2277-2290.

Baştuğ, M., & Akyol, H. (2012). The level of prediction of reading comprehension by fluent reading skills. *Journal of Theoretical Educational Science, 5*(4), 394-411.

Berninger, V., Abbott, R., Cook, C., & Nagy, W. (2016). Relationships of attention and executive functions to oral language, reading, and writing skills and systems in middle childhood and early adolescence. *Journal of Learning Disabilities, 50*(4), 434-449. doi:10.1177/00222 19415 617167

Bildiren, A., & Korkmaz, M. (2018). TONİ-3 zekâ testinin üstün yetenekli çocuklarda güvenirlik ve geçerlilik incelemesi. *Ankara Üniversitesi Eğitim Bilimleri Fakültesi Özel Eğitim Dergisi*, *19*(3), 403-421. doi:10.21565/ozelegitimdergisi.338727

Brown, L. Sherbenou, R. J., & Johnsen, S. K. (1997). Manual of test of nonverbal intelligence (3rd ed.). Austin, TX: PRO-ED.

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

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

Catts, H. W., Adlof, S. M., & Weismer, S. E. (2006). Language deficits in poor comprehenders: A case for the simple view of reading. *Journal of Speech, Language, and Hearing Research*, *49*(2), 278-293.

Chall, J. S. (2013). The gerat debate: Ten years later, with a modest proposal for a reading stage. In B. Resnick & P. A. Weaver (Eds.), *Theory and practice of early reading* (pp. 29-56). NJ: Routledge.

Christopher, M. E., Miyake, A., Keenan, J. M., Pennington, B., DeFries, J. C., Wadsworth, S. J., … Olson, R. K. (2012). Predicting word reading and comprehension with executive function and speed measures across development: A latent variable analysis. *Journal of Experimental Psychology: General, 141*(3), 470-488. doi:10.1037/a0027375

Cromley, J. G., & Azevedo, R. (2007). Testing and refining the direct and inferential mediation model of reading comprehension. *Journal of Educational Psychology*, *99*(2), 311-325.

Cutting, L., Materek, A., Cole, C., Levine, T., & Mahone, E. (2009). Effects of fluency, oral language, and executive function on reading comprehension performance. *Annals of Dyslexia, 59*(1), 34-54. doi:10.1007/s1188 1-009-0022-0

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

Davidson, M. M., Kaushanskaya, M., & Weismer, S. E. (2018). Reading comprehension in children with and without ASD: The role of word reading, oral language, and working memory. *Journal of Autism and Developmental Disorders*, *48*(10), 3524-3541.

Demirtaş, Ç. P., & Ergül, C. (2019). Düşük okuma başarısı gösteren çocuklarda okuma, sesbilgisel farkındalık, hızlı isimlendirme ve çalışma belleği becerilerinin incelenmesi. *Ankara Üniversitesi Eğitim Bilimleri Fakültesi Dergisi*, *53*(1), 209-240.

Dolean, D. D., Lervåg, A., Visu-Petra, L., & Melby-Lervåg, M. (2021). Language skills, and not executive functions, predict the development of reading comprehension of early readers: Evidence from an orthographically transparent language. *Reading and Writing*, 34, 1491-1512.

Ehri, L. C. (1997). Learning to read and learning to spell are one and the same, almost. In C. A. Perfetti, L. Rieben, & M. Fayol (Eds.), *Learning to spell: Research, theory, and practice across languages* (pp. 237-269). New Jersey: Erlbaum.

Ergül, C., & Demir, E. (2017). *SED indeksi ebeveyn bilgi formu*. Yayınlanmamış proje raporu.

Ergül, C., Ökçün- Akçamuş, M., Akoğlu, G., Kılıç-Tülü, B., & Demir, E. (2021). İlkokul çocuklarına yönelik geliştirilmiş Okuma Yazma Değerlendirme Bataryasının (OYAB) geçerlik ve güvenirlik çalışması. *Ana Dili Eğitimi Dergisi*, *9*(3), 740-770.

Ergül, C., Yılmaz, Ç. Ö., & Demir, E. (2018). 5-10 yaş grubu çocuklara yönelik geliştirilmiş çalışma belleği ölçeğinin geçerlik ve güvenirliği. *Eğitimde Kuram ve Uygulama*, *14*(2), 187-214.

Florit, E., & Cain, K. (2011). The simple view of reading: Is it valid for different types of alphabetic orthographies?. *Educational Psychology Review*, *23*(4), 553-576. doi:10.1007/s10648-011-9175-6

Follmer, D. J. (2018). Executive function and reading comprehension: A meta-analytic review. *Educational Psychologist*, *53*(1), 42-60. doi:10.1080/00461520.2017.1309295

Fuchs, L., Fuchs, D., Hosp, M., & Jenkins, J. (2001). Oral reading fluency as an indicator of reading competence: A theoretical, empirical, and historical analysis. *Scientific Studies of Reading*, *5*(3), 239-256.

Gathercole, S. E., Alloway, T. P., Willis, C., & Adams, A.-M. (2006). Working memory in children with reading disabilities. *Journal of Experimental Child Psychology*, *93*(3), 265-281.

Goff, D., Pratt, C., & Ong, B. (2005). The relations between children's reading comprehension, working memory, language skills and components of reading decoding in a normal sample. *Reading and Writing*, *18*(7-9), 583-616.

Gough, P. B., & Tunmer, W. (1986). Decoding, reading, and reading disability. *Remedial and Special Education*, *7*(1), 6-10. doi:10.1177/074193258600700104

Hoover, W. A., & Gough, P. B. (1990). The simple view of reading. *Reading and Writing: An Interdisciplinary Journal*, *2*(2), 127-160. doi:10.1007/bf004 01799

Irak, M. (2009). Duyumdan bilişe: Bilgi işleme süreçlerinin temel öğeleri ve işleyişine yönelik nörobiyolojik, nöropsikolojik ve davranışsal yaklaşımlar. In M. Irak (Ed.), *Psikopatolojilerde bilgi işleme süreçleri, kuramdan uygulamaya* (pp. 3-38). Ankara: HYB Yayıncılık.

Johann, V., Könen, T., & Karbach, J. (2020). The unique contribution of working memory, inhibition, cognitive flexibility, and intelligence to reading comprehension and reading speed. *Child Neuropsychology*, *26*(3), 324-344.

Joubert, S., Beauregard, M., Walter, N., Bourgouin, P., Beaudoin, G., Leroux, J. M., … Lecours, A. R. (2004). Neural correlates of lexical and sublexical processes in reading. *Brain and Language*, *89*(1), 9-20.

Kendeou, P., Papadopoulos, T. C., & Kotzapoulou, M. (2013). Evidence for the early emergence of the simple view of reading in a transparent orthography. *Reading and Writing*, *26*(2), 189-204. doi:10.1007/s11145-012-9361-z

Kibby, M. Y., Marks, W., Morgan, S., & Long, C. J. (2004). Specific impairment in developmental reading disabilities: A working memory approach. *Journal of Learning Disabilities, 37*(4), 349-363.

Korkmaz, M., Bildiren, A., Demiral, N., & Çulha, D. G. (2018). TONI-3 Sözel Olmayan Zeka Testinin 6-11 yaş örneklemi norm ve standardizasyon çalışması [Special issue]. *Anadolu Psikiyatri Dergisi*, *19*, 76-83.

Kuhn, M. R., Schwanenflugel, P. J., & Meisinger, E. B. (2010). Aligning theory and assessment of reading fluency: Automaticity, prosody, and definitions of fluency. *Reading Research Quarterly*, *45*(2), 230-251.

Lanfranchi, S., Jerman, O., & Vianello, R. (2009). Working memory and cognitive skills in individuals with down syndrome. *Child Neuropsychology*, *15*(4), 387-416.

Lee Swanson, H. (2011). Dynamic testing, working memory, and reading comprehension growth in children with reading disabilities. *Journal of Learning Disabilities*, *44*(4), 358-371.

Locascio, G., Mahone, E. M., Eason, S. H., & Cutting, L. E. (2010). Executive dysfunction among children with reading comprehension deficits. *Journal of Learning Disabilities*, *43*(5), 441-454.

Masoura, E., Gogou, A., & Gathercole, S. E. (2020). Working memory profiles of children with reading difficulties who are learning to read in Greek. *Dyslexia, 27*(3), 312-324. doi:10.1002/dys.1671

Messer, D., Henry, L., & Nash, G. (2016). The relation between executive functioning, reaction time, naming speed, and single word reading in children with typical development and language impairments. *British Journal of Educational Psychology, 86*(3), 412-428. doi:10.1111/bjep.12115

Montgomery, J. W. (2000). Verbal working memory and sentence comprehension in children with specific language impairment. *Journal of Speech, Language, Hearing Research, 43*(2), 93-308.

Montgomery, J. W., Magimairaj, B. M., & Finney, M. (2010). Working memory and specific language impairment: An update on the relation and perspectives on assessment and treatment. *American Journal of Speech-Language Pathology*, *19*(1), 78-94.

Morgan, P. L., Farkas, G., Hillemeier, M. M., Pun, W. H., & Maczuga, S. (2019). Kindergarten children's executive functions predict their second-grade academic achievement and behavior. *Child Development*, *90*(5), 1802-1816.

Nation, K., Adams, J. W., Bowyer-Crane, C. A., & Snowling, M. J. (1999). Working memory deficits in poor comprehenders reflect underlying language impairments. *Journal of Experimental Child Psychology*, *73*(2), 139-158.

Nevo, E., & Bar-Kochva, I. (2015). The relations between early working memory abilities and later developing reading skills: A longitudinal study from kindergarten to fifth grade. *Mind, Brain, and Education, 9*(3), 154-163.

Nevo, E., & Breznitz, Z. (2011). Assessment of working memory components at 6 years of age as predictors of reading achievements a year later. *Journal of Experimental Child Psychology*, *109*(1), 73-90.

Nouwens, S., Groen, M. A., Kleemans, T., & Verhoeven, L. (2020). How executive functions contribute to reading comprehension. *British Journal of Educational Psychology*, *91*(1), 169-192. doi:10.1111/bjep.12355

Oakhill, J. V., & Cain, K. (2012). The precursors of reading ability in young readers: Evidence from a four-year longitudinal study. *Scientific Studies of Reading*, *16*(2), 91-121.

Oakhill, J. V., Cain, K., & Bryant, P. E. (2003). The dissociation of word reading and text comprehension: Evidence from component skills. *Language and Cognitive Processes*, *18*(4), 443-468.

Oakhill, J. V., Yuill, N., & Garnham, A. (2011). The differential relations between verbal, numerical and spatial working memory abilities and children's reading comprehension. *International Electronic Journal of Elementary Education*, *4*(1), 83-106.

Öney, B., & Durgunoğlu, A. Y. (1997). Learning to read in Turkish: A phonologically transparent orthography. *Applied Psycholinguistics, 18*(1), 1-15. doi:10.1017/S014271640000984X

Öztürk, A., Elmastaş Dikeç, B., & Tekok Kılıç, A. (2009). Dikkat ve çalışma belleğine gelişimsel nöropsikolojik bakış. In M. Irak (Ed.), *Psikopatolojilerde bilgi işleme süreçleri, kuramdan uygulamaya* (pp. 65-70). Ankara: HYB Yayıncılık.

Palladino, P., & Ferrari, M. (2013). Interference control in working memory: Comparing groups of children with atypical development. *Child Neuropsychology*, *19*(1), 37-54.

Palladino, P., Cornoldi, C., De Beni, R., & Pazzaglia, F. (2001). Working memory and updating processes in reading comprehension. *Memory & Cognition*, *29*(2), 344-354.

Peng, P., & Goodrich, J. M. (2020). The cognitive element model of reading instruction. *Reading Research Quarterly*, *55*(1), S77-S88.

Peng, P., Barnes, M., Wang, C., Wang, W., Li, S., Swanson, H. L., … Tao, S. (2018). A meta-analysis on the relation between reading and working memory. *Psychological Bulletin*, *144*(1), 48-76.

Perfetti, C., & Stafura, J. (2014). Word knowledge in a theory of reading comprehension. *Scientific Studies of Reading*, *18*(1), 22-37.

Perfetti, C. A., Landi, N., & Oakhill, J. (2005). *The acquisition of reading comprehension skill.* In M. J. Snowling & C. Hulme (Eds.), *Blackwell handbooks of developmental psychology. The science of reading: A handbook* (pp. 227-247). New Jersey: Blackwell Publishing. doi:10.1002/9780470757642.ch13

Petersson, K. M., Silva, C., Castro-Caldas, A., Ingvar, M., & Reis, A. (2007). Literacy: A cultural influence on functional left-right differences in the inferior parietal cortex. *European Journal of Neuroscience*, *26*(3), 791-799.

Pikulski, J. J., & Chard, D. J. (2005). Fluency: Bridge between decoding and reading comprehension. *The Reading Teacher*, *58*(6), 510-519.

Purpura, D. J., Schmitt, S. A., & Ganley, C. M. (2017). Foundations of mathematics and literacy: The role of executive functioning components. *Journal of Experimental Child Psychology*, *153*, 15-34.

Rapp, D. N., van den Broek, P., McMaster, K. L., Kendeou, P., & Espin, C. A. (2007). Higher-order comprehension processes in struggling readers: A perspective for research and intervention. *Scientific Studies of Reading*, *11*(4), 289-312.

Reiter, A., Tucha, O., & Lange, K. (2005). Executive functions in children with dyslexia. *Dyslexia, 11*(2), 116-131. doi:10.1002/dys.289

Savage, R., Cornish, K., Manly, T., & Hollis, C. (2006). Cognitive processes in children's reading and attention: The role of working memory, divided attention, and response inhibition. *British Journal of Psychology*, *97*(3), 365-385.

Savage, R., Lavers, N., & Pillay, V. (2007). Working memory and reading difficulties: What we know and what we don't know about the relationship. *Educational Psychology Review*, *19*(2), 185-221.

Seigneuric, A., & Ehrlich, M. F. (2005). Contribution of working memory capacity to children's reading comprehension: A longitudinal investigation. *Reading and Writing: An Interdisciplinary Journal, 18*(7-9), 617-656. doi:10.1007/s11145-005-2038-0

Sesma, H. W., Mahone, E. M., Levine, T., Eason, S. H., & Cutting, L. E. (2009). The contribution of executive skills to reading comprehension. *Child Neuropsychology, 15*(3), 232-246. doi:10.1080/09297040802220029

Silva, C., Faísca, L., Ingvar, M., Petersson, K. M., & Reis, A. (2012). Literacy: Exploring working memory systems. *Journal of Clinical and Experimental Neuropsychology*, *34*(4), 369-377.

Silva, M., & Cain, K. (2015). The relations between lower and higher level comprehension skills and their role in prediction of early reading comprehension. *Journal of Educational Psychology*, *107*(2), 321-331.

Spencer, M., & Wagner, R. K. (2018). The comprehension problems of children with poor reading comprehension despite adequate decoding: A meta-analysis. *Review of Educational Research*, *88*(3), 366-400.

Stanovich, K. E. (1991). Discrepancy definitions of reading disability: Has intelligence led us astray?. *Reading Research Quarterly, 26*(1), 7-29. doi:10.2307/747729

Swanson, H. L., & Beebe-Frankenberger, M. (2004). The relationship between working memory and mathematical problem solving in children at risk and not at risk for serious math difficulties. *Journal of Educational Psychology, 96*(3), 471-491. doi:10.1037/0022-0663.96.3.471

Swanson, H. L., & Berninger, V. (1995). The role of working memory in skilled and less skilled readers' comprehension. *Intelligence, 21*(1), 83-108. doi:10.1016/0160-2896(95)90040-3

Swanson, H., Howard, C. B., & Saez, L. (2006). Do different components of working memory underlie different subgroups of reading disabilities?. *Journal of Learning Disabilities*, *39*(3), 252-269.

Swanson, H. L., & O'Connor, R. (2009). The role of working memory and fluency practice on the reading comprehension of students who are dysfluent readers. *Journal of Learning Disabilities*, *42*(6), 548-575.

Swanson, H. L., Ashbaker, M. H., & Sachse-Lee, C. (1996). Learning disabled reader's working memory as a function of processing demands. *Journal of Experimental Child Psychology, 61*(3), 242-275.

Swanson, H. L., Zheng, X., & Jerman, O. (2009). Working memory, short-term memory, and reading disabilities: A selective meta-analysis of the literature. *Journal of Learning Disabilities, 42*(3), 260-287.

Thomason, M. E., Race, E., Burrows, B., Whitfield-Gabrieli, S., Glover, G. H., & Gabrieli, J. D. E. (2009). Development of spatial and verbal working memory capacity in the human brain. *Journal of Cognitive Neoruscience, 21*(2), 316-332.

Torppa, M., Georgiou, G. K., Lerkkanen, M. K., Niemi, P., Poikkeus, A. M., & Nurmi, J. E. (2016). Examining the simple view of reading in a transparent orthography: A longitudinal study from kindergarten to grade 3. *Merrill-Palmer Quarterly*, *62*(2), 179-206.

Ülper, H. (2018). Yabancı dil olarak Türkçe öğrenen öğrencilerin akıcı sözcük ve metin okuma becerileriyle kavrama becerileri arasındaki ilişkinin karşılaştırılması. *Dil Eğitimi ve Araştırmaları Dergisi*, *4*(1), 1-11.

van den Broek, P., Mouw, J., & Kraal, A. (2016). Individual differences in reading comprehension. In P. Afflerbach (Ed.), *Handbook of individual differences in reading: Reader, text, and context* (pp. 138-150). New York, NY: Routledge.

Van der Leij, A., & Morfidi, E. (2006). Core deficits and variable differences in Dutch poor readers learning English. *Journal of Learning Disabilities*, *39*(1), 74-90.

Verhoeven, L., & van Leeuwe, J. (2008). Prediction of the development of reading comprehension: A longitudinal study. *Applied Cognitive Psychology*, *22*(3), 407-423. doi:10.1002/acp.1414

Wang, S., & Gathercole, S. E. (2013). Working memory deficits in children with reading difficulties: Memory span and dual task coordination. *Journal of Experimental Child Psychology*, *115*(1), 188-197.

Zhang, S., & Joshi, R. M. (2020). Longitudinal relations between verbal working memory and reading in students from diverse linguistic backgrounds. *Journal of Experimental Child Psychology*, *190*, 104727.

ZhenZhu, Y., Ming, Z., & XiaoLin, Z. (2008). Updating verbal and visuospatial working memory: Are the processes parallel?. *Chinese Science Bulletin*, *53*(14), 2175-2185.

Ziegler, J. C., & Goswami, U. (2005). Reading acquisition, developmental dyslexia and skilled reading across languages: A psycholinguistic grain size theory. *Psychological Bulletin, 131*(1), 3-29.