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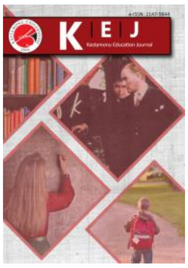

| Review Article / Derleme Makalesi |

Dyslexia and Working Memory: Understanding Reading Comprehension and High Level Language Skills in Students with Dyslexia

Disleksi ve İşleyen Bellek: Disleksi Olan Öğrencilerde Okuduğunu Anlama ve Üst Düzey Dil Becerileri

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Keywords

1. Dyslexia
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Abstract

Dyslexia is defined as difficulties determining speech sounds and learning the relationships of speech sounds with letters and words. Children with learning disabilities may experience problems in attention, memory, perception, motor processing, information processing speed, planning and problem-solving skills. Although lack of phonological processing is considered one of the leading causes of dyslexia, the level of influence of other underlying factors such as cognitive deficits on reading gain is still unclear. Numerous studies have shown that dyslexia is associated with poor working memory, a critical component of reading skill acquisition because the temporary processing of newly introduced and previously stored information involves critical thinking, use of cognitive executive skills, comprehension, and learning tasks. Working memory is often used synonymously with short-term memory, but some theorists consider their functions distinct in that working memory allows for the manipulation of the information temporarily stored in short-term memory. Working memory, which provides preservation, integration and processing of verbal and visual-spatial information, works together with short-term memory to help the mind manipulate and determine important information while temporary. This study discussed the effects of working memory on reading, reading comprehension, and high-level language skills.

Öz

Disleksi, konuşma seslerini algılamada ve konuşma seslerinin harfler ve kelimelerle ilişkisini öğrenmede yaşanan güçlükler olarak tanımlanmaktadır. Dislektik çocuklar dikkat, hafıza, algı, motor işlem, bilgi işleme hızı, planlama ve problem çözme becerilerinde sorunlar yaşayabilirler. Fonolojik işleme eksikliği disleksinin ana nedenlerinden biri olarak kabul edilse de, bilişsel eksiklikler gibi diğer altta yatan faktörlerin okuma kazanımı üzerindeki etkisinin düzeyi hala belirsizdir. Çok sayıda çalışma, disleksinin okuma becerisi edinmenin kritik bir bileşeni olan zayıf işleyen bellek ile ilişkili olduğunu göstermiştir. Çünkü yeni tanıtılan ve önceden depolanmış bilgilerin geçici olarak işlenmesi, eleştirel düşünme, bilişsel yürütme becerilerinin kullanımı, anlama ve öğrenme görevlerinde yer almaktadır. İşleyen bellek genellikle kısa süreli bellekle eşanlamlı olarak kullanılır, ancak bazı teorisyenler işlevlerinin farklı olduğunu düşünürler. Çünkü işleyen bellek, kısa süreli bellekte geçici olarak depolanan bilgilerin işlenmesini sağlar. Sözel ve görsel-uzaysal bilgilerin korunmasını, bütünleştirilmesini ve işlenmesini sağlayan işleyen bellek, kısa süreli bellekle birlikte çalışarak önemli bilgilerin manipüle edilmesine ve belirlemesine yardımcı olur. Bu çalışmada çalışma belleğinin okuma, okuduğunu anlama ve üst düzey dil becerileri üzerindeki etkileri tartışılmıştır.

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INTRODUCTION

A learning disability is defined as a specific difficulty in mastering the primary language, mathematical, or other skills unrelated to intelligence (Bajre & Khan, 2019), usually diagnosed when a child begins schooling. Students with learning disabilities constitute more than 50% of those who need special education. The most common learning disability, dyslexia or specific reading difficulty, negatively affects the academic life of learners (Cortiella & Horowitz, 2014) as they experience problems at the level of phonological awareness that interferes with reading comprehension and fluency and completion of reading tasks (Fletcher et al., 2019). 20% of dyslexic individuals also have attention deficits and weakness in motor skills, and 50% have deficits in visual focusing. Inadequacy in motor skills can lead to weakness in using psychomotor skills to coordinate acceptable muscle mechanisms. Problems in timing and lack of adaptation, especially in fine motor skills, are closely related to reading acquisition (Rao et al., 2021).

Dyslexia has been divided into two categories, developmental and superficial phonological dyslexia. Developmental dyslexia is a neurological deficiency that makes reading acquisition difficult (Mortimore, 2008) for individuals who have no problems with cognitive and affective skills. Phonological dyslexia is the specific inability to effectively use semantic, morphological, phonological, and visual information. Individuals with phonological dyslexia have difficulty distinguishing words due to insufficient visual memory. While problems understanding word affixes and incomplete reading of syllables are defined as morphological errors, the inability to read due to unrecognizable word codes when encountering obscure words is defined as phonological deficiency (Hulme & Snowling, 2016; MacKenzie, 2015).

In this review, following an examination of the components of working memory, the relationship between working memory and reading comprehension and high-level language skills in children with dyslexia are examined. Also, the effect of working memory on phonological and mental changes in understanding reading and its relation to problems with high-level language skills are investigated. This study aims to contribute to research on and practice in preparing effective curricula, developing effective teaching strategies, and providing appropriate educational environments for children with dyslexia..

Memory and Cognition

Memory, including the ability to store memories, is a primary brain function in the individual's development of a sense of self and the ability to reason, understand, and, of course, learn (Protopapas & Parrila, 2018). To examine the relationship between dyslexia and working memory, it is of critical importance to understand the concept and types of memory and the processing of information into memory (Parrila et al., 2020). In cognitive psychology, memory is conceptualized in three stages: coding, storage and access (Austin et al., 2014).

Coding refers to the process of grasping, processing and combining information, achieved by physical and chemical mechanisms operating through our senses. Storage refers to the process of ensuring the persistence of encoded information over time (Romani et al., 2015). Retrieval refers to the process of recovering the information required for a transaction or activity. This process involves finding the needed information and transferring it to consciousness. Such recalling can be easy or difficult depending on the type of information (Bosse et al., 2015). Figure 1 illustrates the three types or stages of memory through which information must pass before being permanently stored: sensory memory, short-term memory/working memory, and long-term memory (Melby-Lervåg et al., 2016). Short-term memory/working and long-term memory may weaken with age or due to clinical conditions or other factors that disrupt memory processes (Randall, 2007).

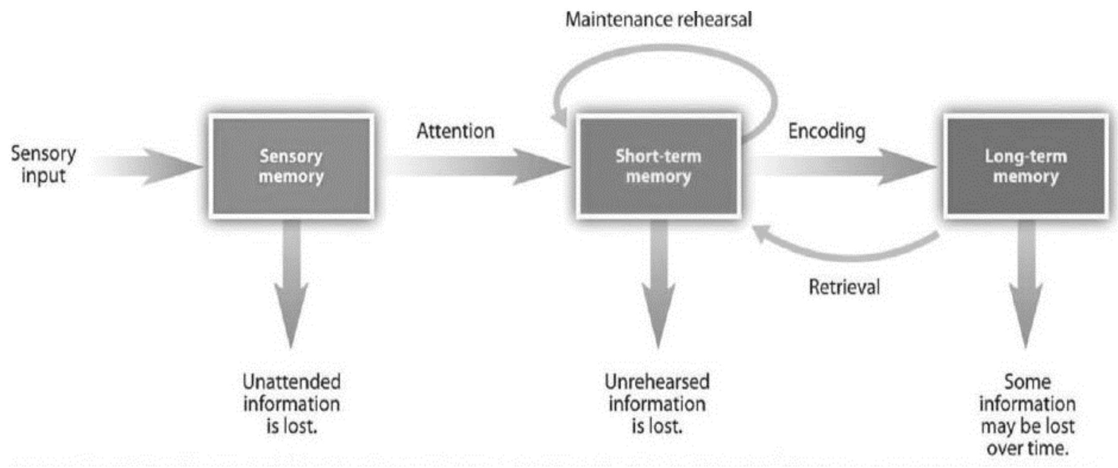

Figure 1. Stage of memory

Sensory memory is the first step in processing the information we receive from the outside through sight, hearing, touch, smell and taste. In sensory memory, the information obtained through the sensory organs is briefly stored before being transferred to short-term memory. Because of the brevity of sensory memory, if the information is not immediately transferred to short-term memory for processing, it is lost (Maehler & Schuchardt, 2016).

In short-term memory, information is temporarily stored just long enough for processing. Just as sensory memory is a necessary step toward short-term memory, it is a necessary step for long-term memory, which involves working memory, a component of short-term memory which helps direct the memory process of receiving and organizing information, making it a critical element of the learning process (Parrila et al., 2020). For example, working memory is engaged when solving an arithmetic problem without paper. Also, one uses working memory to bake a cake efficiently without diverging into a long rhetorical argument, employing partially preserved information, or adding the same ingredient twice (Ottem et al., 2007).

Long-term memory allows information to be durably persevered for as long as a lifetime. kept in mind continuously. Long-term memory is a system that has limited capacity yet contains an unlimited amount of information. The essential function of long-term memory is its role in complex tasks such as problem-solving, social interaction, decision making, and reflecting on important moments in one's life (Ottem et al., 2007). Accessibility of Information stored in long-term memory varies. For example, some memories are relatively easy and others more challenging to retrieve. Three basic memory types are involved in storing long-term memories: procedural memory, semantic memory, and episodic memory (Maehler & Schuchardt, 2016). Procedural memory includes memories associated with learning, such as the motor skills involved in skating, cycling or running. Semantic memory stores general information, including the meanings of words, and is of vital importance to academic learning. Episodic memory stores information about experiential events such as one's first day of school, one's wedding day, or the birth of one's child (Dahlin et al., 2008).

Working Memory and Dyslexia

Working memory is often used synonymously with short-term memory, but some theorists consider their functions distinct in that working memory allows for the manipulation of the information temporarily stored in short-term memory. Working memory, which provides preservation, integration and processing of verbal and visual-spatial information, works together with short-term memory to help the mind manipulate and determine important information while in temporary storage (Baddeley, 2006). Studies of working memory address daily cognitive activities that require both processing and storage, such as mental arithmetic and comparative reasoning. However, working memory capacity is limited, and a loss of information in working memory may occur due to cognitive overload during an ongoing activity due to excessive storage or information processing requests (Ottem et al., 2007).

Working memory is a critical component of the learning process as it undertakes essential tasks related to the retention and processing of information to be transferred to long-term memory and its integration with previously stored information. Working memory supports cognitive skills for comprehension, learning new information, critical thinking, and memory updates (Reis et al., 2020). To help execute tasks that require attention and focus, subsystems in working memory store and process auditory, verbal, and visual information. Focusing is essential for the completion of these tasks and the cognitive processes associated with memory (Baddeley, 2006). Students with working memory problems may have trouble absorbing lessons and completing learning activities because working memory plays essential roles in decoding and comprehension in reading, solving problems in mathematics and expressing ideas in writing. Therefore, understanding the relationship between working memory and dyslexia and related learning disabilities is critical in planning educational adaptations (Schwarb et al., 2016).

Reading is a complex process that can be explained in terms of a series of cognitive factors, including sensory inputs, working memory, and higher-level cognitive processes (Alloway & Alloway, 2010). Although deficit in phonological processing is accepted as one of the leading causes of dyslexia, the effects of underlying factors and the levels of influence of other cognitive deficiencies on reading acquisition are still uncertain (Warmington et al., 2013). However, there are two alternative neurocognitive explanations of dyslexia. One focuses on a fundamental deficiency in the rapid temporal perception of auditory and visual information, while the other focuses on fundamental shortcomings in skill automation (Bosse et al., 2015).

Numerous studies have shown that dyslexia is associated with poor working memory. Compared with individuals with average reading ability, it has been observed that dyslexic individuals display poor working memory functions (Fischbach et al., 2014). In order to understand the relationship between working memory and dyslexia, it is helpful to closely examine the structural functions of working memory. As seen in Figure 2, the working memory is conceptualized as consisting of (i) central executive, (ii) visual-spatial scratchpad and (iii) phonological loop (Warmington et al., 2013).

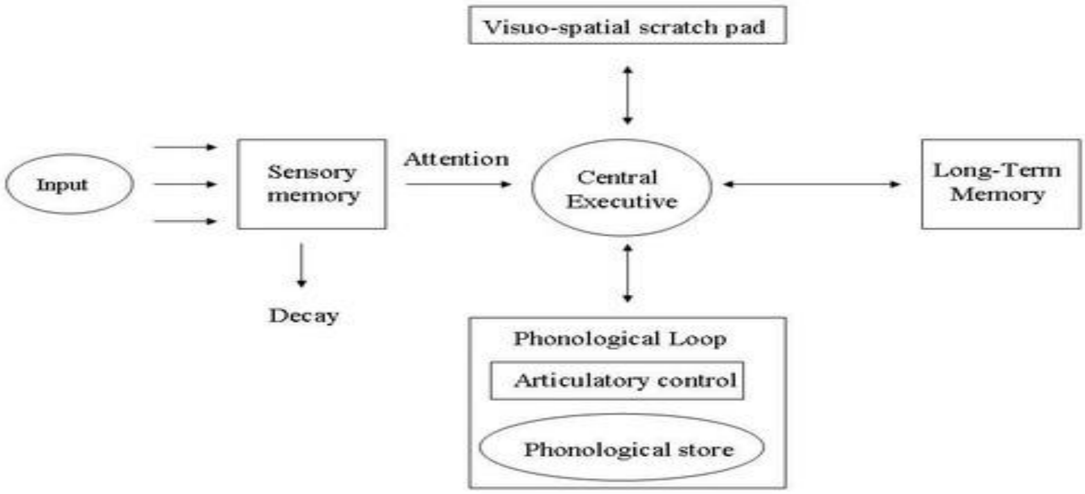

Figure 2. Working memory model

As seen in Figure 3, The central executive is the principal component of the information processing dimension of the working memory. By undertaking many cognitive functions, the central executive gives the working memory the role of manager or central coordinator of metacognitive processes (Fischbach et al., 2014). Strategic use of limited working memory capacity and reprocessing of information that is consciously or unconsciously recalled from long-term memory are other essential functions of the central executive. The central executive combines auditory and verbal phonological information and visual-spatial information. Verbal working memory and visual-spatial working memory are activated according to the type of information coming to the central executive (Hamouda & El-Shafaei, 2021).

The executive working memory organizes its tasks using the principles of blocking, switching, and updating, without which the individual cannot manage or make sense of tasks that require a constant flow of information such as reading (Montogmery & Evans, 2009). Blocking is the process of suppressing information about non-urgent tasks or thoughts. Switching refers to the transition between two tasks. Switching entails organizing relationships between existing processes and rehearsing information held in short-term memory. Updating is the processing of new information that will replace existing information (Fischbach et al., 2014).

Phonological working memory recognizes words by processing the phonological codes. Studies (Wagner & Muse, 2006; Milton, 2008) show that phonological awareness and phonological working memory duration are highly correlated (correlation coefficient: 0.88). Phonological working memory incorporates a phonological loop specialized for short-term storage and manipulation of speech-related stimuli (Montogmery & Evans, 2009). For the phonological processes to be carried out perfectly, the phonological working memory capacity must be fully utilized. Therefore, phonological processing skill is directly related to working memory capacity. Individuals who encounter severe problems in reading are identified as having phonologic disorders (Gutierrez-Clellen et al., 2004). People with phonologic disorders are known to be at risk for related, or co-occurring, problems in phonological awareness, language comprehension and written language (Couture & McCauley, 2000).

When phonological working memory receives auditory and phonologically perceived information, it automatically correlates with relevant sounds kept in long-term memory (Montogmery & Evans, 2009). With automatic subvocal rehearsal, the short-term storage capacity of the phonological working memory is increased, and the cognitive load is reduced. Also, subvocalization, or silent speech, is the inner speech typically performed during the reading that helps the reader correctly pronounce words mentally or orally (Miller & Kupfermann, 2009). This phenomenon, which is a natural process in compelling reading, potentially reduces cognitive load by helping the individual grasp the meaning and remember what is read. If the dyslexic individual does not rehearse sufficiently, the functioning of the phonological working memory decreases significantly (Hartsuiker & Barkuysen, 2006). However, rehearsal has some limits. Regardless of age, the person must have pronounced the corresponding sound or word within two seconds. The ideal speech rate is determined by the amount of information rehearsed in the working memory in a short period (two seconds maximum). Unfortunately, due to the lack of rehearsal and the amount of information retained in the phonological working memory, dyslexic individuals are generally relatively slow at both explicit and latent articulation (Pickering, 2006). Therefore, the diagnosis of reading difficulty can be made by closely examining the individual's phonological working memory (Miller & Kupfermann, 2009 because word recall difficulties detected in the analysis of phonological working memory are accepted as a symptom of language and reading difficulties (Menghini et al., 2011). Tasks that involve immediate sequential recall of letters, sounds, numbers, and words are used in evaluations of phonological working memory (Miller & Kupfermann, 2009).

Visual-spatial working memory, also known as the visual-spatial sketchpad, stores information about objects and their positions in space. Visual-spatial information can be static or dynamic (Dehn, 2014). Static information includes only the colors or shapes of items (Miller & Kupfermann, 2009). Dynamic information consists of stimuli in motion or stimuli that the individual has to manipulate, such as imagining how puzzle pieces fit together. The information kept in the visual-spatial working memory is constantly updated. The rehearsal of the information transferred visually-spatially is performed by re-imaging (Montogmery & Evans, 2009). Cognitive tests feature many tools for measuring visual-spatial working memory, especially inert materials (Kim & Lombardino, 2017). Until recently, the role of visual-spatial working memory was not considered necessary in reading, but it has been determined that visuospatial working memory plays an essential role in phonetic decoding of long words and keeping these words in memory for a while (Westerberg & Klingberg, 2007). For example, the processes of keeping each morpheme in an extended written word such as “Antarctica” in the memory and reading them together take place in the visual-spatial working memory (Kim, Wiseheart, & Walden, 2018).

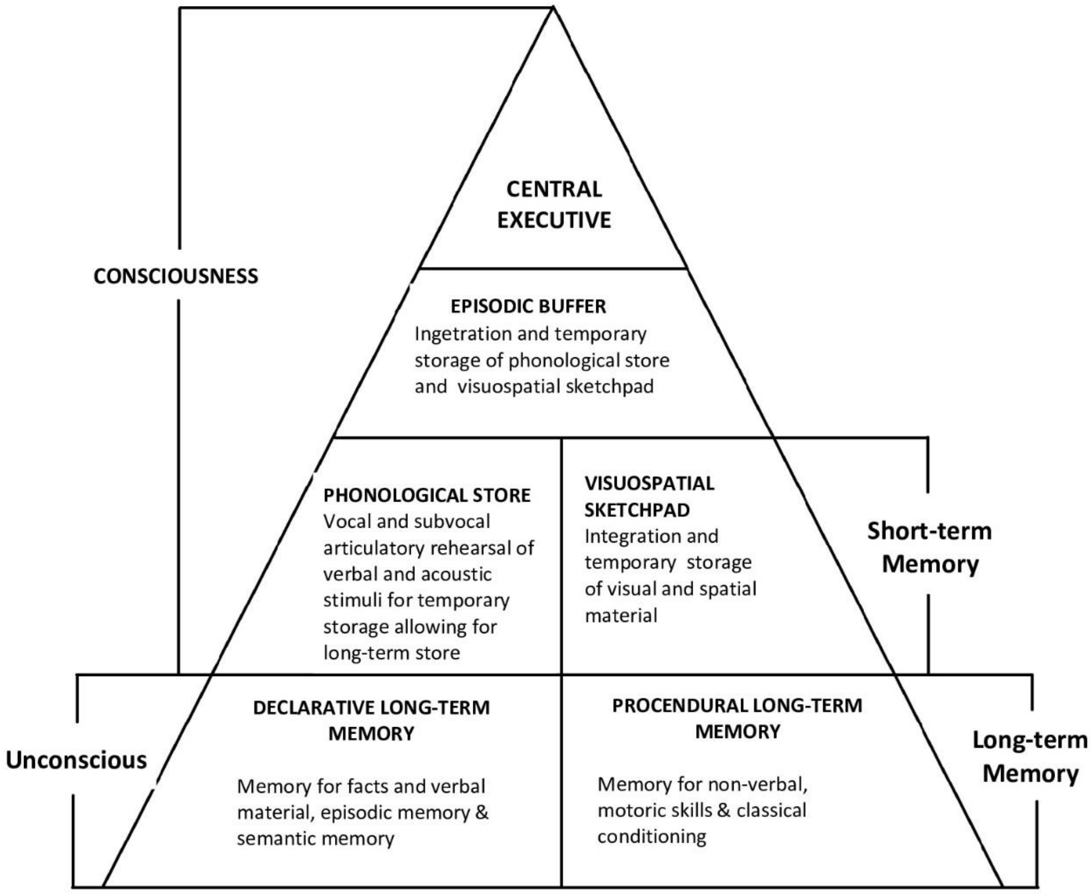

Figure 3. Major components of working memory

Working Memory and Cognitive Load

The amount of information that can be processed in the limited capacity of working memory is referred to as cognitive load (Gathercole & Alloway, 2004). Excessive cognitive load can slow down processing or cause processing errors (Klingberg, 2009). This relationship is twofold. Effective use of working memory depends on fast, back and forth transitions and rehearsal in processing the briefly stored information (Dahlin, 2011). Sweller (1988) argued that, because working memory has a limited capacity, instructional methods should avoid overloading it with additional activities that do not directly contribute to the target learning.

Cognitive load theory differentiates three types of cognitive load: intrinsic, extraneous, and germane. Intrinsic cognitive load is the difficulty inherent to a specific instructional topic or task. All instructional tasks have an inherent difficulty associated with them (e.g., calculating 2 + 2 versus solving a differential equation) (Sweller, 1988). While this inherent difficulty cannot be altered, an instructor may divide a schema into "subschemas," teach them separately, and then bring them back together to teach the combined whole (Paas, 1992). Extraneous cognitive load is generated by how information is presented to learners and can be attributed to the design of the instructional materials. Because there is a single limited mechanism using finite cognitive resources to process the extraneous load, the amount of resources available to process the intrinsic and germane loads (i.e., learning) is reduced (Sweller & Cooper, 2009). Thus, extraneous cognitive load is under the control of instructional designers. Materials should be designed to reduce the extraneous load, especially when the intrinsic and germane load is high (e.g., when a problem is complex). For example, a teacher can describe a square using either a verbal or figural medium (Loosli et al.). Indeed, the teacher can explain a square in words, but a square is a figure and can be understood with much less effort if learners are shown a square

(Sweller & Cooper, 2009). In this instance, the figural medium is preferred because it does not burden the learner with unnecessary information or extraneous cognitive load (Sweller, 1988).

Germane cognitive load is the processing, construction and automation of schemas that constitute learning. While the intrinsic cognitive load is generally thought to be immutable (although techniques of segmenting and sequencing can be applied to manage complex material), instructional designers can manipulate extraneous and germane load. It is suggested that they limit extraneous load and promote germane load (Sweller, 1988).

Decoding increases the cognitive load during reading, and the cognitive load affects the reader's level of understanding. The decoding process's relatively less developed automaticity imposes more cognitive load (Spironelli et al., 2010) and decreases the working memory capacity for comprehension. As the individual gains reading fluency (automaticity), the cognitive load decreases and s/he will have more working memory capacity for comprehension (Montogmery & Evans, 2009).

Reading Comprehension Skills in Dyslexia Students

The simplistic view of reading is that a student's ability to understand written words depends on how well s/he can sound out (decode) words and understand their meanings (Diamanti et al., 2018). Reading comprehension can be predicted by multiplying skills in decoding the written words by the ability to understand the meanings of those words. However, language involves many other cognitive processes such as comprehension, problem-solving, and intelligence (Martinelli & Fenech, 2017). In this context, there is a close relationship between vocabulary, language comprehension and reading skills, which are essential requirements for reading comprehension (Cain et al., 2004). Studies have shown that while verbal working memory is significantly associated with early reading achievement, it is only a part of a general phonological processing structure related to reading rather than a causal factor, and other components of working memory are also active in reading (Kibby et al., 2004; Van der Leij, & Morfidi, 2006).

Decoding and fluency are mainly related to phonological and visual-spatial working memory, and reading comprehension is primarily related to executive working memory. Converting graphemes to phonemes, that is, decoding depends on the visual-spatial working memory capacity, and combining graphics codes is a time-consuming process in the working memory (Moser et al., 2007). In regular reading, graphemes are matched with phonemes, and all-new visual stimuli coming to working memory are re-encoded (Savage et al., 2007). Decoding in reading occurs in phonological working memory (Baddeley, 2003). If there is difficulty in decoding even though the average phonological working memory capacity is sufficient, the order of the phonemes cannot be rehearsed subvocally; that is, the phonological working memory cannot be used effectively (Malaia et al., 2009). Word blending from the codes in the phonological working memory occurs in the executive working memory (Moser et al., 2007).

The reading difficulties of individuals with developmental dyslexia have been attributed to a deficiency in phonological processing, for which a variety of explanations have been proposed, including deficits in phonological awareness and verbal memory (Provazza et al., 2019). Recent investigations suggest that developmental deficits in reading acquisition may co-occur with visual processing deficits, which are particularly salient for visually complex stimuli, yet these deficits have received relatively little attention from researchers (Cain et al., 2004). Dyslexic individuals have trouble synchronously transferring sequential and verbal information such as letters, phonemes, words, and expressions to the phonologically working memory. Examples of phonological working memory impairment are as follows (Smith-Spark & Fisk, 2007):

1. Inability to store phonemes for word blending
2. Forgetting the coded phonemes before sending them to the central executive
3. Forgetting the order of phonemes
4. Inability to keep words long enough for comprehension to take place

There is conflicting evidence as to whether people with dyslexia are better than, the same as, or worse than non-dyslexics at visuospatial processing tasks, with many of the differences, found being the result of task demands. Recent studies have found that visual-spatial storage capacity and visual-spatial processing are insufficient in children with dyslexia (Giovagnoli et al., 2016; Martinelli & Fenech, 2017). Also, Fischbach et al. (2014) found that subjects with dyslexia had a critical deficiency in the processing and storing dynamic visual-spatial information, although they had an average ability to store static visual-spatial information. However, Bosse and Valdois (2009) found that developmental dyslexia is associated with weaknesses in visuospatial working memory's static and dynamic aspects. These studies indicate that even if the visual-spatial storage capacity is average, information can be lost in working memory during synchronous processing. Based on the relationship between storage and cognitive load in individuals with dyslexia, memory studies suggest that they can ignore some visual-spatial information during processing to reduce cognitive load (Stein, 2014).

A reader must keep a sufficient number of words and sentences in memory in order to be able to comprehend the text read and to determine the main ideas. However, reading comprehension puts a heavy cognitive load on the central executive (Moser, Fridriksson & Healy, 2007). Individuals with an enhanced central executive working memory capacity are more successful in comprehending the text read and integrating the information obtained to conceptualize the meaning of longer passages (Skarakis-Doyle & Dempsey, 2008). Phonological and visual-spatial working memory storage components are not highly related to reading comprehension processes (Diamanti et al., 2018). Besides vocabulary knowledge and word decoding, comprehension depends heavily on higher-level processes, such as integration of text information with prior knowledge in the context of inference generation and simile comprehension, as well as on metacognitive control processes involved in comprehension monitoring (Chrysochoou et al., 2011). Reading comprehension problems are generally more associated with central executive functional processing deficits (De Beni et al., 2007).

High-Level Language Skills in Dyslexia Students

Decoding and word recognition, related to phonological skills, are the first step of understanding the reading process (Cavalli et al., 2017). Understanding is the process of interpreting the relationships among words in syntactical contexts by making inferences and determining their deep structure (Dehaene, 2014). Reading entails using both low-level and high-level cognitive skills, which depend on the performance of certain mental and procedural functions (Purpura & Ganley, 2014). The low-level language skill components can be listed as phonics (phonological context), decoding and repeating auditory information (working memory), and decoding phoneme and morpheme codes and the relationship between them rapidly enough to make sense of the word (word reading). High-level language skills depend on the combination of vocabulary (comprehending the word and interpreting it within the syntactical structure) and cognitive information (being able to analyze and use strategies to determine to mean) (Del Tufo & Earle, 2020). In their most general definition, high-level language skills refer to metacognitive mental processes such as thinking, perception, and remembering (Silva & Cain, 2015). Therefore, high-level language skills are essential for academic and social success beyond vocabulary knowledge and grammar skills. They include advanced comprehension skills such as acquiring and integrating new vocabulary, understanding relationships between words from syntactic context, interpreting sentences, and comprehending the text holistically (Rhea, 2001). In addition, phonology, syntax, morphology, semantics have critical importance in language skills. For example, understanding humor, interpreting body language, and drawing inferences from what is read (Kintsch & Kintsch, 2005) or heard are common indicators of high-level language skills (Alloway et al., 2006). Possession of high-level language skills enables individuals to advance their control over the micro and macro structures of language and the practical and flexibility of the language they use or interpret. Drawing Inferences helps the reader make sense of the text gaps and grasp its implicit meanings. As a result, individuals who effectively use high-level language skills can become independent and critical readers (Cain et al., 2004).

While decoding problems naturally cause dyslexic individuals to have difficulties understanding the context of the text, their reading problems are also due to their inability to organize verbal tasks and lower-upper-level cognitive skills (Smith-Spark et al., 2017). Although vocabulary and grammar are a source of difficulty in reading comprehension for individuals with dyslexia, it is more difficult for them to perform tasks requiring higher-level skills such as listening or reading comprehension and monitoring of complex texts, which require the ability to establish inference and meaning relationships (Hulme & Snowling, 2011). Dyslexic individuals who have problems with high-level language skills are likely to exhibit insufficient ability to draw inferences and inadequate comprehension monitoring skills (Olander et al., M. 2017). Cain et al. (2004), in an examination of the relationship between high-level language skills and working memory in reading comprehension, found that verbal working memory does not have a direct effect on the comprehension of sentences, inference skills, and simple syntax or semantics (Liu et al., 2019). On the other hand, it has been determined that verbal working memory is directly involved in verbal expression, especially in the stages of sentence conceptualization and word formations. Individuals with high-level language skills can readily retrieve words with their intended meanings from long-term memory and efficiently organize these words in the correct syntax within verbal working memory. In addition, they actively and effectively use executive working memory to coordinate word order while speaking fluently (Moser et al., 2007). In addition to adequate executive working memory, adequate phonological storage for receptive and expressive language skills is also essential (Baddeley, 1990). Individuals with incomplete or insufficient high-level language skills often experience situations such as having difficulty understanding words, not correctly using words with different meanings, not perceiving rhymed words, having insufficient phonological awareness, and being generally unable to express their feelings and thoughts (Hulme & Snowling, 2011).

Bishop and Snowling (2004) present a two-dimensional model of the relationship between children with dyslexia and children with language impairment. Children with language impairment have difficulty in the primarily non-phonological language skills of syntax and morphology, while children with dyslexia have impairments primarily in phonological processing. Given that successful reading comprehension requires phonological knowledge for decoding, children with dyslexia may have difficulty reading comprehension due to the complex nature of translating the sounds of their language into meaningful text for comprehension (Araújo & Faísca, 2019). For this reason, children with dyslexia who have primary difficulty with phonological aspects of language continue to exhibit impairments in reading comprehension while they may have relative strengths in oral language comprehension (Hulme & Snowling, 2011). Understanding the functional communication abilities of children with dyslexia, who often have comorbid impairments in at least one of the dimensions of language identified above, is essential to ameliorate their language difficulties and should be an additional goal of educational interventions for dyslexia. Narrative language is one context in which functional language ability may be evaluated in children with dyslexia. The behaviors observed in dyslexic children who have difficulty using high-level language skills are as follows (Rhea, 2001):

- Academic failure,
- Poor social relationships,
- Inability to make connections among and semantic interpretations of words in sentence contexts,
- Difficulty understanding verbal and written expressions,

- Weakness in writing skills,
- Difficulty understanding humor, riddles, and joke narratives

Evidence-Based Working Memory Interventions

It is possible to increase memory performance by applying memory strategies and metacognitive control (Maehler et al., 2019). Two main methods are often used to reduce the difficulties caused by poorly working memory. One includes classroom adaptations to minimize cognitive load to facilitate the child's learning (Elliott et al., 2010; Gathercole & Alloway, 2008). The other method focuses on teaching individuals to use memory strategies to improve working memory and increase memory efficiency (Clair-Thompson et al., 2010).

Classroom adaptations focus on increasing teachers' awareness of working memory problems and encouraging them to adapt their teaching approaches to reduce learners' working memory load (Yang et al., 2017). Teachers are also encouraged to use instructional strategies that help learners with poor working memory overcome cognitive weaknesses (Gathercole et al., 2008; Holmes et al., 2010). This approach is based on principles designed to motivate learners with low working memory by helping them reduce errors and increase self-confidence. The recommendations of this intervention are as follows:

- To identify the areas in which students with poor working memory capacity have difficulty, tasks that require complex mental processes can be given to test the limits of working memory.
- To identify warning signs of cognitive overload, the teacher can observe how the student copes with cognitively challenging activities. Asking simple questions (such as "What will you write?") can reveal whether the student has forgotten important information during an activity.
- Learning activities that reduce the cognitive load in working memory can be developed. By simplifying complex activities, the number of information students need to remember can be reduced, and their awareness of the significance of the material used in the activity can be increased. The number of steps in the activities can be reduced, and a prolonged activity can be divided into shorter segments. In addition, new materials can be associated with previously acquired knowledge, and language structures can be simplified, and the length of sentences can be reduced in explanations of complex activities,
- Partnering students with poor working memory with students who do not have this problem can provide peer support and increase motivation.
- The student can be taught to use memory aids such as wall charts and posters, spelling lists of frequently used words, personalized dictionaries, counters, number lines, multiplication tables, calculators, memory cards and sound recorders. In addition, the student may be taught to bolster weak memory skills through such means as rehearsal, note-taking, creating flowcharts and diagrams, applying organizational strategies, and making connections between new and previously learned information to support long-term memory.

The second approach focuses on improving the efficiency of dyslexic students' working memory by educating them to use specific goal-oriented strategies that require mental effort (Holmes & Adams, 2006). Repeating the information that needs to be remembered aloud, creating sentences or stories using words the student has difficulty remembering, or representing information with visual imagery are examples of these strategies (Dunlosky & Kane, 2007).

Rehearsal can be particularly helpful in information processing by allowing students with dyslexia to keep more information in working memory for a more extended period (Minear & Shah, 2006). Rehealing is the most basic and straightforward memory strategy, entailing only the repetition of information with low levels of cognitive processing. Readers with standard working memory capacity can perform rehearsal semi-automatically without requiring full attention or taxing working memory capacity. It has been found that the rehearsal strategy improves recall and academic learning in individuals younger than five years old (Lehmann, 2015). However, while a simple rehearsal strategy is used frequently with five or six learners, it is not often or regularly used as a cognitive strategy with learners between the ages of seven and ten (Compton et al., 2020). Another way to support a dyslexic student with poor working memory is to minimize the cognitive load during reading (Lehmann, 2015). Some ways to implement this strategy are as follows:

- Providing a quiet environment can prevent noise and distractions from increasing cognitive load.
- Having the student read texts on the familiar subject can provide a supportive context to insert new words rather than presenting them in isolation. In this way, phonological complexity can be reduced, and an increase in cognitive load can be prevented.
- Excessive verbalization during reading, which adds to cognitive load and slows momentum, can be reduced by providing nonverbal clues in the text such as pictures.
- Providing frequent breaks during reading can alleviate information overload and prevent students from becoming bored or fatigued.

- Finally, an individualized review program can be created to assess each student's progress on an ongoing basis. These reviews and evaluations can be conducted (a) at the end of a lesson, (b) the following day, (c) after a two- or three-day delay, and (d) after another two or three days, and (e) two weeks after the last review.

RESULTS

In recent years, growing awareness of the nature and causes of learning difficulties has increased the number of studies conducted in this area, producing a rich and multi-dimensional body of literature. The present study contributes to this literature by reviewing the cognitive dimensions of reading comprehension and high-level language skills in dyslexic students focusing on working memory processes. The most apparent signs of dyslexia include failure to decode phonemes and morphemes, skipping, adding to texts, and interpreting words differently from their intended meanings. These difficulties negatively affect these students' metacognitive skills and their daily life skills. Students with poor working memory tend to have trouble planning, organizing, and carrying out routine chores that require mentally formulating a "to do" list organized by time and location. Study skills may also suffer. Working memory allows one to keep track of priorities and helps block the external or internal distractors that can derail one from the task at hand. Working memory thus helps one persist with tasks that require focused attention over time. Even strong working memories can experience working memory problems when overly tired, anxious, or stressed.

Working memory is also key to (a) accessing information held in long-term semantic memory stores to provide the meaning and pronunciation of words; (b) holding and sequencing sounds for spelling and composing, holding, and connecting ideas in written text.; and (c) achieving reading comprehension and reading fluency. When reading a long sentence, paragraph or passage, working memory allows one to hold on to and integrate information read early with information that comes later. Students with solid decoding skills but weak working memories often comment that they "cannot remember anything!" from a page that they just read.

Poor working memory can make it difficult for learners to acquire the phonological skills needed for decoding sounds. These difficulties affect reading negatively by reducing the speed of reading and comprehension. In addition, weakness in the short-term storage of phonological information negatively affects the decoding process by making it difficult to remember a series of phonemes long enough to blend them (Holmes & Adams, 2006). Also, to apply grammar rules and understand the text, the visual-spatial information must be processed in the visual-spatial working memory and interpreted, stored, and retained in the phonological working memory under the management of the central executive. The reader with poor executive control over working memory has difficulties understanding what s/he reads as the deficiency prevents information updating, modifying, and error tracking (Skarakis-Doyle & Dempsey, 2008). In addition, excessive cognitive load reduces the working memory capacity required for reading comprehension processes. Therefore, during the decoding process, the individual's cognitive load can be minimized, and his/her comprehension of the text being read is facilitated by directly supporting the repetition of phonemes just before word collation.

The most common problem of individuals with dyslexia is their poor phonological working memory storage capacity and lack of high-level language skills focused on understanding the deep structure of the language. It is possible to improve the working memory performance of individuals by providing an appropriate classroom environment and teaching memory strategies. Applying evidence-based strategies can strengthen and support working memory, which can help improve decoding and comprehension.

As conceptualized in the simple view of reading, reading comprehension is the product of accurate and efficient word reading and language comprehension. As dyslexia is related to poor working memory, vague visual-spatial working memory, and the increase in cognitive load due to the prolongation of the decoding process can negatively affect the process of reading comprehension. For this reason, the implementation of appropriate reading programs and classroom strategies for dyslexic individuals and providing appropriate in-service training for teachers can contribute to the academic success of dyslexic individuals.

In conclusion, working memory deficits are now recognized as one of the major defining characteristics of dyslexia. After phonological processing, working memory is the essential cognitive process required for proficient reading. Working memory, phonological, visual-spatial, and executive aspects play essential roles during reading. Therefore, it is imperative that teachers, reading specialists, psychologists, and speech-language pathologists understand specifically how working memory processes are involved with reading processes.

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