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The Role of Memory in Dyslexia

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ABSTRACT

This paper examines what the literature proffers regarding the relationship between dyslexia and memory deficiencies. Dyslexia is a well-known learning disability that has been recognized since the late 1800's and has grown in notoriety since it was first discovered (Javier, 2015). It is especially notable due to its current prevalence among school aged children as well as adults and because of the detrimental nature that impaired literacy can have on their ability to read, write and excel academically. Discussed here are a history of dyslexia, along with a general exploration of the functions of memory and how it has to do with the processing and output of information within the mind. Two research studies are examined that help draw a direct correlation between a deficit in short-term and working memory with the phonological difficulties suffered by those who experience dyslexia. By better understanding the role of memory in dyslexia, educators may be more efficient at assisting and implementing early intervention for those children who need it.

Key words: Dyslexia, Short-term Memory

INTRODUCTION

Learning disabilities are common phenomena encountered by professionals in the field of special education. A learning disability is defined as a condition that may create difficulties for the individual possessing it in acquiring and properly absorbing knowledge and fulfilling academic capabilities to the same level as his or her peers, particularly when the difficulties arise from factors that are not associated with a physical handicap (Baddeley, 1992). Learning disabilities manifest in myriad different disorders; some children face trouble with their concentration levels and attention span, some cannot seem to stay organized, and others face problems when attempting to comprehend the abstract nature of mathematics. Most frequently, learning disabilities present as problems with language-based tasks such as reading, writing and speech (van Genuchten, Cheng, Leseman, & Messer, 2015). Recent studies seem to have largely focused on learning disabilities that fall within the autism spectrum; as a result of this attention, the field of autism studies has garnered increased notice from a variety of sources, from the medical field to mass media outlets. As a consequence of this increased attention on autism studies, other learning disabilities appear to have been overlooked in terms of academic research and commercial attention; dyslexia is one such disability. In the United States, learning disabilities are well known and generally identified within educational facilities. This occurs largely because United States educational institutions can provide faculty with training pertinent to identifying potential learning disabilities (Youman & Mather, 2013). This is done in an effort to facilitate early intervention as a means to assist the child.

Learning disabilities have the potential to impact not only the academic careers of individuals who experience them, but also other facets of their lives. They can cause difficulty making friends, social issues, emotional stress and anxiety as well as problems within families. Reading problems and problems with language affect roughly 3.6 to 7.3 percent of all school-aged children within the United States alone, and 80 percent of those students suffer from developmental dyslexia (Youman & Mather, 2013).

Developmental dyslexia is most commonly referred to simply as dyslexia and is an inherited neurocognitive deficit that results in difficulties in learning and absorbing information (Fischbach, Könen, Rietz, & Hasselhorn, 2014). Literacy learning constitutes the most severe locus of difficulty for individuals with dyslexia, causing such individuals to display difficulties with recognizing words, spelling, and converting patterns of letters into their associated sounds (Tunmer & Greaney, 2010). In addition to these problems with reading and language, individuals with dyslexia can also display problems with memory, and an inability to recognize sequencing aspects within the execution of basic mathematics (Youman & Mather, 2013).

Like most learning disabilities, the severity of dyslexia lies within a diagnosis spectrum that ranges from very mild to severe (Vogel, 2003). One of the defining traits of dyslexia involves its connection to poor functioning memory (Vogel, 2003). Children and adults suffering from dyslexia may find

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that their short-term and working memory may not be as functional as those around them (Elftorp, 2015). This paper seeks to examine the connection between dyslexia and short-term memory impairment through the examination of scientific research and academic journals that explore the topic in-depth. Arriving at a thorough and accurate understanding of the relationship between dyslexia and short-term memory impairment requires this sort of careful examination of the literature. As a foundation to this sort of examination, it is important first to establish the appropriate context by outlining dyslexia's historical and medical background.

OVERVIEW OF DEVELOPMENTAL DYSLEXIA

Dyslexia is categorized as a medical syndrome (Elftorp, 2015). It is classified as such to express that it encompasses a set of characteristics that are exhibited differently, and are evident in varying degrees, from individual to individual (Elftorp, 2015). A number of questions surround dyslexia; at present, for example, there is no specific scientific explanation as to its origin, nor is there any explanation for why certain people are afflicted with dyslexia rather than others (Elftorp, 2015). While it is known that dyslexia is genetically inherited, the disorder's root cause remains a mystery (Elftorp, 2015).

Dyslexia functions as a grouping of characteristics exhibited differently by and seen in varying degrees in different individuals (Baddeley, 2015). Most often these characteristics cause learning difficulties for the individuals possessing them. However, just as often, those who suffer from dyslexia may also possess distinctive talents and high intelligence ("The Yale center for dyslexia and creativity," 2015). Clearly, therefore, dyslexia is not correlated with low intelligence, nor is it indicative of low educational potential (Elftorp, 2015). The syndrome does not discriminate in terms of race or socioeconomic status (Elftorp, 2015). While economic status and race are not predictive demographics of the prevalence of dyslexia, gender appears to play a role in how likely it is to become manifest (Elftorp, 2015). Current figures state that the rate of dyslexia sits at 3:1 for males and 5:1 for females, meaning that males are 1.4 to 3 times more likely to be diagnosed with the disorder (Fischbach et al., 2014). The reason for male propensity of dyslexia occurrence remains unknown.

Although the field of psychological examination into the causation of specific learning disabilities has expanded significantly in the last hundred years, there is still debate over dyslexia's specific characteristics (Alloway & Gathercole, 2006; Berninger, 2001). It is agreed upon the dyslexia is an inherited neurocognitive deficit that results in difficulties in learning and absorbing information (Baddeley, 1992). Current research indicates that two thirds of all dyslexia cases stem from genetic causations (Ramus et al., 2003). Additionally, Anyanwu and Campbell (2001) provided evidence of a connection between difficulties in childbirth and the development of dyslexia later in life. Experts believe that up to four percent of the American population may be experiencing a significant presentation of the syndrome and that up to six percent may also mildly experience dyslexia (Ramus et al., 2003). Because dyslexia is so prevalent among American children, and because it may be detrimental to learning, it is important to attempt to understand what is known about the medical background of the syndrome.

HISTORY OF DYSLEXIA

The medical history of dyslexia begins in the late 1800s when medical interest in reading difficulties began to be investigated by curious physicians (Javier, 2015). The syndrome was first medically recognized around 1870, when the Forster Education Act initiated the creation of a public school system to educate every child within the country of England (LD Online, 2015). As British schools began to come online, a notable pattern associated with difficulty reading began to become apparent to educators (LD Online, 2015). This raised medical concerns of local doctors, who then began to examine possible causes for the trend. In the late 1870's, as word of this trend began to spread, a German neurologist named Andrew Kussmaul began to examine the phenomenon within his home city of Stuttgart (Javier, 2015). He became interested in further examining patients who seemed to display difficulty in reading and in word usage. Particularly interesting to Kussmaul was the tendency of the individuals he studied to place words incorrectly within the sentences they constructed (Javier, 2015).

In 1887 another German doctor, Rudolf Berlin, had heard of Kussmaul's work and eventually coined the term *dyslexia* as a descriptor for the condition (Javier, 2015). *Dyslexia* is a Greek word whose translation means "difficulty with words" (Javier, 2015). The first diagnosed case of dyslexia occurred in 1896 in England and was reported by the journal *British Medical*. This was the first recorded medical record of dyslexia in modern society (LD Online, 2015). The English doctors who recorded the instance were an ophthalmologist named Hinshelwood and a general medicine practitioner named Pringle-Morgen (LD Online, 2015). They both believed that dyslexia was caused by a "congenital word blindness" (LD Online, 2015), meaning that they believed that those with dyslexia were afflicted with a disorder that was caused by an impaired ability to visually process the words and symbols placed before them. It would be another 27 years before further work would be done in the field regarding possible causes for dyslexia. In 1925 Dr. Samuel Orton, an American neurologist, would come up with an alternate theory for the causation of dyslexia (Javier, 2015). He claimed that difficulty in reading was not a visual deficiency but that it may be a problem resulting from the dominance of one side of the brain over the other (Javier, 2015).

The focus on the field of study regarding learning disabilities began to expand in 1939 with the works of Dr. Alfred Struss and Heinz Wurner (Javier, 2015). These two German scholars worked together to become pioneers in the field of learning difficulties and they identified a number of learning disabilities (Tulving & Schacter, 1990). The most important aspect of their work stems from their idea that there are a variety of disorders that can cause learning difficulties and that each individual child be seen as a unique case that should be assessed and evaluated as such (Tulving & Schacter, 1990).

True breakthroughs in the field of learning disabilities, including dyslexia, occurred in the middle of the twentieth century when the focus on methods of research switched

from a medical perspective to the field of psychology in relation to education (Javier, 2015). With a growing understanding of child development, dyslexia had the potential to be better understood through both the medical workings of the mind and psychological aspects of these childhood conditions. As these developments occurred within the field, psychologists were able to link emerging research on impaired functions of memory with some of the characteristics of dyslexia that involved a deficit in the ability to read, write or memorize mathematical processes (Tulving & Schacter, 1990). In most cases, dyslexia can now be identified through an educational evaluation (Javier, 2015). Such evaluations attempt to determine whether or not a student possesses a "low working memory" ("The Yale center for dyslexia and creativity," 2015). In one of the examples of an evaluation, educators seek to explore test subjects' memory capabilities by asking them to explore a multi-step task and assessing whether or not they struggle to accurately recall and perform the task efficiently ("The Yale center for dyslexia and creativity," 2015). It has been found that dyslexia may be present when a student displays an inability to solve multi-step problems without resorting to some sort of external medium, such as a scratch pad, to supplement his or her memory (Javier, 2015). Students who display problems of this sort are often submitted for further testing to ascertain whether or not they may be dyslexic due to their "low working memory" ("The Yale center for dyslexia and creativity," 2015).

MEMORY

Because this paper examines the extant literature concerning the relationship between dyslexia and memory problems, it is critical that the scientific concept of memory be explained in a manner that helps to create clarity in the examined research. Memory is a concept that humans have long-tried to understand. The model of memory that currently prevails is that outlined by Atkinson and Shiffrin (1968); it divides memory into three discrete processes: sensory memory, short-term memory, and long-term memory.

Sensory Memory

The initial memory function, sensory memory, involves temporary storage of information received from the environment via the senses (Atkinson & Shiffrin, 1968). As humans encounter different forms of information, the mind only pays attention to certain aspects of what was received and that information is then passed into the short-term memory (Atkinson & Shiffrin, 1968).

Short Term Memory

Short-term memory functions as the venue in which information gathered from the senses is retained for a somewhat lengthier period of time than sensory memory so that it can be processed more fully (Atkinson & Shiffrin, 1968). Short-term memory can be usefully compared to a sort of temporary mailbox attached to a shredder. A piece of information comes in, it is examined and utilized, and then, when its usefulness is exhausted, it goes straight to the shredder and into the trash bin. The storage duration of information in short-term memory is approximately 20 to 30 seconds, though that period can be extended by the use of rehearsal techniques (Alloway & Gathercole, 2006). Short-term memory also seems to have a cap on the number of items it can contain; a famous study by Miller (1956) concluded that the capacity of short-term memory is seven items, plus or minus one or two, at any given time.

Long Term Memory

If short-term memory can be compared to a temporary mailbox and shredder, long-term memory can be usefully compared to a large, full, and organized filing cabinet. Long-term memory is described as a means of continued storage of information within the mind (Tulving & Schacter, 1990). The majority of information that exists within long-term memory is gathered unconsciously (Tulving & Schacter, 1990). Though the information stored in long-term memory is retained for lengthy periods, it varies in accessibility: some memories can be relatively easy to recall, while others are much harder to reach. There are three intrinsic components involved in creating long-term memories: procedural memory, semantic memory and episodic memory (Tulving & Schacter, 1990). Procedural memory involves memories that are associated with instruction and learning how to do things that have to do with the development of motor-skills such as roller skating, riding a bike, or running (Tulving & Schacter, 1990). Semantic memory stores information about the world, including memories involving knowledge gained through academic study as well as general knowledge, including the meaning of words (Tulving & Schacter, 1990). Episodic memories are memories of experiences, such as one's first day of school, one's wedding day, or the birth of a first child (Tulving & Schacter, 1990). Discrete long-term memories usually do not consist of just one of the memory types described above; frequently they combine some or all of them (Tulving & Schacter, 1990). Perhaps the most crucial aspect of long-term memory is the fact that it can be accessed by the mind for a variety of purposes: solving problems, interacting socially, making decisions, or simply revisiting important moments in one's life (Tulving & Schacter, 1990).

Working Memory

Working memory operates in conjunction with short-term memory to assist the mind in its manipulation, sorting, and filing of important information and subconscious knowledge that is to only be utilized in temporary storage (Baddeley, 1992). Working memory is important to distinguish from short-term memory because the two function separately but also work together to lead the memory process into retrieving information. Working memory is characterized as a critical element of the learning process (Alloway & Gathercole, 2006). This is because of its role in the temporary holding and processing of newly introduced and previously stored data (Alloway & Gathercole, 2006). These are critical elements involved in any activity that has to do with critical

thinking, the utilization of reasoning skills, comprehension, learning new information and memory updates (Alloway & Gathercole, 2006). The importance of working memory in the completion of these tasks has to do with the nature of the subsystems that act as a key component in working memory (Alloway & Gathercole, 2006). These subsystems store and manipulate auditory, verbal and visual information in order to complete tasks that require attention and focus (Alloway & Gathercole, 2006). In order to complete these tasks, it is necessary to involve the cognitive processes involved in short-term memory as well as an ability to hold one's attention (Alloway & Gathercole, 2006). When problems arise within the working memory process, they can lead to difficulties that can, in turn, result in the development of a learning disability. Students who exhibit impairment of their working memory may experience trouble remembering class instructions and experience trouble with learning activities (Alloway & Gathercole, 2006). As such, this explanation of memory is critical in understanding the relationship between memory and its role in dyslexia. The most critical role of working memory is that of temporarily holding information that will then be transferred into long-term memory; this role facilitates learning (Fischbach et al., 2014).

LITERATURE REVIEW

Recent innovations in research indicate that there is a connection between the functions of working and short-term memory and the development of dyslexia, especially in cases where reading and memory problems are especially problematic (Alloway & Gathercole, 2006). Extensive research and evidence on the role of working memory has indicated that there is a definitive connection between learning outcomes and the efficiency of working memory in phonological tasks (Fischbach et al., 2014). By examining two of these studies we can identify exactly how and why certain researchers conducted their research and were able to determine a connection between memory and dyslexia. The first of these research projects examined the parameters of working memory and short-term memory as they related to those who had dyslexia and those who did not (Alves Ferreira de Carvalho, de Souza Batista Kida, Aparecida Capellini, & Brandão de Avila, 2014). The second, a three year longitudinal research project, sought to explore and confirm the connection between deficits in working memory and those associated with literacy disorders such as dyslexia (Fischbach et al., 2014). Each of these studies helps to reinforce the connection between memory and dyslexia and examining the claims within these studies can help us to elucidate on the possible implications of how we might be able to assist in countering the negative effects of dyslexia on those who show learning impairment.

STUDY ONE

Purpose

The first study examined was conducted by students from the special educational studies department at São Paulo Federal University in São Paulo, Brazil in 2014 (Alves Ferreira de Carvalho et al., 2014). They sought to explore the connection of the working memory to its effect on phonological processing. Phonological processing refers to the patterns that children utilize to simplify, comprehend, and use adult speech and speech patterns (Beneventi, Tønnessen, Hugdahl, & Ersland, 2010). All children utilize phonological processing while their speech and language skills take form and develop throughout childhood (Beneventi et al., 2010). The researchers refer to an interest in the current assumption that the proper functioning of the working memory is a critical element of the ability to properly process and decode the written word (Alves Ferreira de Carvalho et al., 2014). Their study functioned as part of a larger study being conducted within their college that focused on reading comprehension in dyslexia. This specific portion of the study looked specifically at abilities that enable reading comprehension (Alves Ferreira de Carvalho et al., 2014).

Method

The researchers studied one hundred and fifteen students whose ages ranged from eight to 15 years. The students were divided into two separate groups: 98 students who had no difficulty in reading or listening comprehension made up one of these groups; the other consisted of 17 individuals who had been identified as dyslexic (Alves Ferreira de Carvalho et al., 2014). The criteria for the comparison group was proficiency at language-based functions in school and a positive outlook on academics (as reflected by lack of complaints noted by teachers, particularly about reading-related work) (Alves Ferreira de Carvalho et al., 2014). Both groups were administered identical tests, and the results of those tests were recorded and subjected to statistical analysis.

The administered tests asked students to complete a number of tasks designed to gauge the function of their working and short-term memories. One of the tasks involved asking the students to complete tasks of repetition of "pseudowords" (made up words that are unfamiliar to test subjects) and digits (Alves Ferreira de Carvalho et al., 2014). Students were asked to repeat the psuedowords back to the tester as accurately as possible and their accuracy was recorded. Next, after being asked to remember a series of seven-digit numbers, the students were instructed to repeat the numbers in both normal and reverse order (Alves Ferreira de Carvalho et al., 2014). A subsequent section of the assessment designed to examine the test subjects' skills with word coding and oral dictation of text asked subjects to listen to a recorded narrative and answer questions about what they heard (Alves Ferreira de Carvalho et al., 2014). In addition, test subjects were asked to read portions of text and were evaluated for accuracy and clarity. A third section of the assessment focused on reading comprehension. In this section, researchers asked the test subjects to read four age-appropriate narrative pieces; the researchers then asked the test subjects six questions about the text that aimed to assess the subjects' comprehension (Alves Ferreira de Carvalho et al., 2014). The data collected was analyzed using the Mann-Whitney Test in order to compare data points and make deductions based on the results (Alves Ferreira de Carvalho et al., 2014).

Findings

The results showed that students in the control group performed better at almost every task given to them during the study. They were better able to recall the pseudowords and digits given to them, and they were better at reading comprehension and answering text-connected questions (Alves Ferreira de Carvalho et al., 2014). The subjects in the dyslexic group performed worst in the repetition of pseudowords and numbers (Alves Ferreira de Carvalho et al., 2014). Although the control group scored better in almost every category, the dyslexic group fared well with questions connected to the auditory narrative.

Conclusions

The researchers concluded that this study worked to confirm what they had already assumed to be true, that those who are classified as dyslexic struggle with aspects of their short-term and working memory when it comes to phonological processing (Alves Ferreira de Carvalho et al., 2014). They also remarked that the markedly lower performance of the dyslexic subjects in the repetition segment of the assessment was the best indicator of a failure of some component of working memory (Alves Ferreira de Carvalho et al., 2014). In summation, the researchers concluded that the tests and the result of their assessments succeeded in helping to provide additional proof of a link between dyslexia and a phonological disorder, proof that suggested a connection between dyslexia and a deficiency in short-term memory (Alves Ferreira de Carvalho et al., 2014).

STUDY TWO

Purpose

The researchers in the second study were part of a team that worked for the German Institute for National Research in Frankfurt, Germany. The goal of the study was to conduct a long-term examination of dyslexic individuals' literacy disorders in connection with working memory deficits (Fischbach et al., 2014). Researchers set out to chart dyslexic students' developmental trajectories over a three year period and to compare the results to those of their "non-disabled" peer group (Fischbach et al., 2014). In order to obtain this information, the researchers focused on areas of study involving reading and spelling to gauge the performance of the short-term and working memory of the students involved (Fischbach et al., 2014). The purpose of their study was to illustrate the correlation between memory deficiencies and phonological performance problems (Fischbach et al., 2014).

Method

The sample examined in this study consisted of 28 children who had previously been diagnosed with dyslexia and exhibited a definitive combination of reading and literacy deficiencies (Fischbach et al., 2014). The control group consisted of 28 children who had no reading or writing difficulty. These children were chosen from a screened group of 1,800 primary school children and those who satisfied the criteria for the research study were invited to take part (Fischbach et al., 2014). Each group was administered tests over the course of a three-year period and the results were recorded and analyzed.

The assessments involved the administration of identical standardized tests to both groups at the beginning of each grade level and then at the completion of the following grade (Fischbach et al., 2014). The tests administered to all test subjects consisted of a standardized written IQ test as well as a combined reading and spelling assessment (Fischbach et al., 2014). These involved portions in which the subjects were asked to read a series of written pieces and then to answer a series of questions designed to assess his or her comprehension level (Fischbach et al., 2014). Researchers utilized techniques similar to the aforementioned research study in that they administered a test involving repetition of non-words (items essentially identical to the "pseudowords" from the previous study) and numerical digits. The subjects were also given a visual matrix test that involved using a touch screen in combination with a sketchpad to match the image of a black square on the screen to a corresponding block on the sketchpad. The purpose of this test was to measure the subjects' working memory capacity for visual static information (Fischbach et al., 2014). The combination of all of these tests sought to examine the function of working memory as it pertains to phonological recall and memory (Fischbach et al., 2014). The results were collected each year and were examined using manifest multi-group models and full information maximum likelihood estimation to assess the working memory function of test subjects (Fischbach et al., 2014).

Findings

The researchers of this study found, much as did those of the previous study, that the control group performed better on all tests involving phonological tasks. The two groups' performances on the visual matrix test, however, were similar, with the dyslexic group outperforming the control group by a small margin (Fischbach et al., 2014). Most notably, the researchers found that while the control group members continued to show improvement in the tested areas as the study progressed; the dyslexic group did not. The study's long-term findings indicated that the dyslexic subjects' difficulties continued to present in a consistent manner, suggesting that children with dyslexia who go without intervention will continue to struggle (Fischbach et al., 2014). Moreover, the researchers found that the dyslexic subjects' problems did not automatically improve with age; instead, the researchers noted that the difficulties sometimes seem to shift to different areas of phonological abilities. These shifts varied from person to person and failed to indicate a notable pattern (Fischbach et al., 2014).

Conclusions

The researcher concluded that the results collected through their study helped to strengthen the connection between an

impairment of working memory and dyslexia. They also determined those who suffer from these phonological difficulties are at a significant disadvantage when compared to their peers and that these complications only seem to grow as the child ages (Fischbach et al., 2014). The researchers concluded that their work demonstrated that the most consistent deficiencies noted in working memory of subjects with dyslexia are related to their overall storage capacity of phonological loop, recall and comprehension when compared with their peers (Fischbach et al., 2014). The researchers also concluded that their study showed that the trajectory of these complications is consistent as the subjects aged (Fischbach et al., 2014).

IMPLICATIONS

The implication of these studies is that the impairment of working memory directly correlates with the phonological difficulties that are the most significant characteristic of dyslexia. Although it had been previously assumed that the connection existed, the studies helped to provide evidence that the mechanical workings of dyslexia lie somewhere within the function of working and short-term memory. As research within the field expands, there may be ways in which focus on the improvement of working memory may be critical as a means to assist those who struggle with reading, literacy and other language-related difficulties. The results of these studies suggest that there is a potential to help create new ways of improving working memory and short-term memory as a means to treat the literacy and phonological issues associated with dyslexia. As of right now, dyslexia is treated through a combination of early intervention and educational tools designed to help facilitate the child in learning to read (UK National Health Service, 2015). These types of studies may open a door to a future approach to dyslexia that will focus more on improving memory as a means of improving performance in phonological learning.

SUMMARY

Dyslexia affects a large amount of children and their ability to learn and excel in the educational system. General education systems tend to involve a one-size-fits-all approach to education that may be detrimental to a child who experiences difficulties in the phonological processing that tends to accompany the diagnosis of dyslexia. As examined here, short-term memory and working memory play a critical role in a child's ability to succeed in tasks involving reading, recall and repetition. It is critical that early intervention be instituted in order to develop a learning plan for those who are diagnosed with dyslexia as a means to enable them to approach methods of learning in manner outside of the one-size-fits-all approach of general education. At the moment, that approach consists of early educational intervention that is primarily focused on developing and strengthening phonological skills and awareness (UK National Health Service, 2015). As previously discussed in this paper, short-term and working memory play a critical role in phonological processing. Further research of this topic may be critical in developing new methods and approaches to helping those who struggle with literacy and educational performance as a result of dyslexia. By further exploring work within the field of memory we have the capabilities to create more in-depth examinations of memory improvement that may be potentially applied as a treatment of the phonological difficulties associated with dyslexia.

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