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Dysphysics. An additional specific learning disability that occurs in individuals with dyslexia or/and dyscalculia

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Abstract. The present study investigated the involvement of working memory deficits in the difficulty presented by individuals with dyslexia or/and dyscalculia to understand Physics. For this reason, it dealt with the working memory deficits in these individuals and with the type of difficulties they face in learning Physics. The study concluded that the deficits in Phonological loop,in visual-spatial sketchpadand central executive that cause difficulties in individuals with dyslexia or/and dyscalculia also cause a learning disability in physics, the dysphysics.

Keywords: Physics, working memory, phonological loop, Visuo-Spatial Sketchpad, central executive ,dyslexia, dyscalculia

Introduction

Physics has immense importance for the individuals and the society because it enhances the thinking process, has application in daily life, contributes to the development of intellectual honesty, promotes the positive attitude, promotes the insight into the scientific processand leads to the social skills development (Zewdie, 2014). But teaching science to individuals with special educational needs (S.E.N.) is less efficient compared to that to individuals without S.E.N (Kirch et al., 2007). Specific Learning Disabilities (SLD) are a type of neurodevelopment disorder that impairs the ability to learn or use academic skills (Tannock, 2014).Among the main types of SLD are developmental dyslexia which is usually referred to simply as dyslexia (Alsulami, 2019)and dyscalculia (Aparna et al., 2023).

Dyslexia is related to difficulties in decoding words, spelling, vocabulary, comprehension, written expression (Cortiella & Horowitz, 2014).Reading is both arduous and slow, with a few errors, or it is fast and abrupt, with many errors. Physics education presents problems for individuals with dyslexia. The text understanding and the orientation in the text is a difficult and very tedious process. Because of slow rate of reading and difficulty in text understanding students need further time to deal with the text. Due to incorrect reading of the text or imperfect comprehension their performance in solving learning tasks is lower. They may also show a lack of understanding of replacing words with symbols. Children with impaired visual perception, right-left and spatial orientation may be wrong in simple calculations or in frequent changes in the algorithm(Trna & Pavlickova, 2014).

Dyscalculia appears more as a difficulty in basic mathematical operations. Characteristics of dyscalculia are for example poor differentiation of geometric shapes, difficulty in recognizing of operations signs and mathematical operations, inability in reading and writing mathematical symbols, in performing of mathematical operations and in understanding of mathematical relationships (Trna & Pavlickova, 2014).The students with dyscalculia have reduced performance in Physics learning tasks because they have difficulty with arithmetic,difficulty on physics units converting and data processing as well as reduced ability to remember and apply physics-mathematics concepts, rules and formulas. They show a lack of ability in self-reflection of a physics learning task solving and inability to explicate the solution of a learning task(Trna et al.,2010).

Research concludes that S.L.D. are associated with the working memory deficits (Maehler & Schuchardt, 2016). The present research will study if the working memory deficits that cause the dyslexia and dyscalculia are also responsible for the problems in understanding Physics faced by individuals with these specific learning disabilities.

Working Memory definition and its components

Working memory (W.M) is considered perhaps the most important achievement of human mental evolution(Campos et.al, 2013). W.M. refers to the system or systems responsible for the temporary storage and manipulation of information necessary while performing complex cognitive tasks like reading, comprehension, reasoning, learning and problem solving (Baddeley,1992,2000,2010).It has a strong effect on differences sections of cognition such as attention, language, processing speed, writing, and mathematics (Pham& Hasson, 2014). It was discovered that the term "Working memory" was originally used in the early computer science literature, not in the psychological research publications. In particular Newell and Simon in 1956 wrote about a complex information processing system called logic theory machine that they designed, competent to find proofs of theorems in symbolic logic(Logie & Cowan,2015;Cowan, 2017;Angelopoulou & Drigas, 2021;Newell & Simon, 1956). The creation of this program was based mainly "on heuristic methods similar to those that have been observed in human problem solving activity" (Newell & Simon, 1956). To achieve this, they created computer memory spaces that they named "working memories", which were able to store data only temporarily during the conduct of certain procedures. The difference between storage memories and working memories is that the first are suitable for more permanent storage of information. Moving all of the data to be processed from storage memories to working memories and back again is necessary (Logie & Cowan, 2015; Cowan, 2017; Angelopoulou & Drigas, 2021; Newell & Simon, 1956).

Miller, Galanter, and Pribram in 1960 invented the term working memory characterizing it as a type of a quick-access memory necessary for carrying out a plan and occupies a specific area in the frontal lobes of the brain (Angelopoulou & Drigas, 2021;Milleret al., 1960). In 1968 Atkinson and Shiffrin considered that short-term memory acts as W.M. and described it as a temporary work areawhich draws information directly from sensory input, processes that information and transfers a proportion of that into long-term memory and they expressed the perception that it has a decisive effect on learning and on cognition more widely (Baddeley,2010; Logie & Cowan, 2015; Atkinson & Shiffrin, 1968). According to the Atkinson and Shiffrin model in individual with short term memory impairments information is quickly lost, so they should be incapable to learn. Additionally if the short-term memory was actually functioning as W.M. patients with short-term memory deficits should be seriously cognitively handicapped. However, researches have shown that these patients can store information in long-term memory and have long-term learning. Baddeley and Hitch to address the weakness of Atkinson and Shiffrin's model introduced instead a three-component W.M. model in 1974 (Baddeley, 2010; Angelopoulou & Drigas, 2021).According to this model ,W.M.comprises an attentional control system called central executive, subserved by two short-term storage systems, the visuo-spatial sketchpad for visual content, and the phonological loop for verbal-acoustic content (Baddeley, 2010; Baddeley & Hitch, 1974). By choosing the term working memory they wanted to point out that it is not limited to the simple storage of information but plays an important role in cognition in generally (Baddeley, 2010). Baddeley in 2000 completed this model with a fourth component, the episodic buffer (Baddeley,2010;Angelopoulou& Drigas, 2021).

The phonological loop is responsible for storing of verbal and aural information through two subsidiary systems it contains, the temporary phonological store and the articulatory rehearsal system (Baddeley, 2000). The phonological store associated with speech perception and retains information in speech-based form for about 2 seconds unless refreshed by articulatory rehearsal. The articulatory rehearsal system linked to speech production and repeats the information in phonological loop to be stored in working memory (Baddeley, 2000; Angelopoulou& Drigas, 2021;Pampori & Malla, 2016)and is considered analogous to sub-vocal speech (Baddeley, 2003). The Visuo-Spatial Sketchpad is responsible for temporarily storing and manipulating visuospatial information being a key tool for spatial orientation and for visuospatial problems solving (Baddeley, 2002). It contains the visual cache and the inner scribe which are separated but cooperate closely with each other. Visual cache is closely linked to visual perception and has the ability to store as visually based codes and process rapidly the visual information such as the shape and color of objects. The visual information fades in about 2 seconds. The Inner Scribe can retains visual codes in the Visual Cache for longer by mentally rehearsing these codes(Logie,1995;Logie, 2011). This subsystem of W.M. is capable to creating an interface between visual and spatial information, which can be accessible through the senses or from long-term memory. So it creates coupling between a variety of visual information channels and similar information of a motor, tactile, or haptic type (Baddeley, 2002). So Visuo-Spatial Sketchpad integrates spatial, visual, and possibly kinesthetic information into a unified representation which may be temporarily maintained and handled (Baddeley, 2003).

The central executive is the most complex system of W.M.. It was initially considered as a mechanism responsible for focusing attention, storage and making decisions described as homunculus a little man in the head that coordinates and controls the function of the slave storage systems. Baddeley came up with that it has three executive capacities. First, it has the ability to focus attention. Its second important feature is the capacity of dividing attention between two important targets or stimulus streams. Third Central executive contributes to the process of switching attention that occurs during switching between tasks (Baddeley, 2002; Baddeley, 2012).

The episodic buffer is a limited-capacity multidimensional temporary storage system that binds information from different sources. It is controlled by the central executive (Baddeley, 2000; Baddeley et al., 2017) and integrates not only information between the visuospatial sketchpad and the phonological loop but also links W.M. with perception and long term memory(Baddeley, 2012). It is capable of weighing up, manipulating and modifying that information (Baddeley, 2000). It allows the other 3 subsystems of W.M as well as the long term memory to interact despite the fact that these ones are based on different codes (Baddeley et al.,2017).

Dyslexia and working memory deficits

Smith-Spark & Fisk, 2007researched the dyslexic and non-dyslexic university students' performance using experimental tasks on PC. Researchers used measures of simple verbal span (digit, letter, and word span) and Corsi block span, complex W.M. span specifically the verbal tests computation span, reading span and the visuospatial test Spatial W.M. span, as well as the Consonant updating and Spatial updating measures. On all the phonological tasks and the spatial W.M. span task, the dyslexic group scored much lower compared to the non-dyslexic group. The fact that impairments persisted on the complex span measures even after the statistical control of simple span performance suggests that a central executive impairment in dyslexic individuals exists. The novelty of task requirements during early trials of the spatial updating task were more difficult for students with dyslexia. So there is a high probability that dyslexic people have supervisory attention system impairment. In conclusion dyslexic people lag behind in both storing information in W.M and processing of them.

Beneventi et al.,2010 dealt with dyslexic and control children's phonological awareness processing in order to determine their cortical activation related to verbal W.M. Researchers utilized a modified WM n-back task and required students to identify the initial or final speech part (phonemes) in the names of common items of which line drawings were presented and were drawn from Snodgrass and Vanderwart norms. Their presentation was controlled by E-prime software and were displayed through MR compatible LCD ‘‘goggles’’ connected to a PC that was not inside the MR chamber. Also the stimuli were displayed in an alternating fMRI blood-oxygenation level dependent (BOLD) ON/OFF-block (box-car) design with 4 different runs. The dyslexic students had impaired performance compared to control readers. fMRI activation in the left superior parietal lobule and the right inferior prefrontal gyrus was much better compared their dyslexic peers. Alsoin WM regions with higher memory load, dyslexic students didn't exhibit a discernible rise in activation. According to these resultsdyslexic children have specific W.M. deficit.

Menghini et al.,2011examined primary and middle school dyslexic and non-dyslexic children's performance. In verbal span task consisting of a number of uncommon word with two syllables, pupilshave to repeat words in the same order that examiner had read. In visual-spatial span task they have to recognize the right sequence of positions in which presented in screen a non-verbalizable geometric shape. In visual-object span task students must remember the right display order of complex geometric figures. In Map Mission subtest they must circle as many targets as possible on a city map. In Code Transmission subtest,they have to keep under systematic review continuous auditory information (digits) for an individual target occurrence and then recognize the digit which occurs right before a particular target sequence. In Visual Perception Test subtest 2, pupils have to find the matching line drawing for each figure in a multiple-choice display that consists of vertically oriented figures and in subtest 4 they must recognize drawings in a confusing setting or within overlapping pictures. The results showed that the W.M deficit for dyslexic children exists not only for verbal content, but also for visual-object and visual-spatial content but their attentional and visual-perceptual problems don't account for this deficit.

Alt et al.,2022 investigated W.M. performance in second grade children with and without dyslexia. Incomprehensive Assessment Battery for Children–W.M.(CABC-WM) that evaluates multiple components of W.M. students had to assist their preferred pirate avatar in problems solving. For Central Executive were used:The Number Updating task in which children had to check the number of yo-yos and teddy bears. The 1-back N-Back tasks that asked students to identify whether anauditory or visual stimulus matched the immediately preceded stimuli. Phonological tasks were the Digit Span that required repeating of increasingly lengthy sequences of digits with a single syllable, Digit Span Running in which a child had to repeat as many numbers, in correct order, as s/he could memorize from the end of a series of numbers with unpredictable length and Nonword Repetition with nonwords repetition. Focus/Visuospatial tasks were used: In Location Span, children indicated where a series of arrows had directed by pointing to right dots positioned in a circle. Location Span Running was similar but they alsomight to rememb er as many locations as they could, in correct order, from the end of a series arrow locations. Visual Span Running was similar, with recalling in correct order, polygons from the end of a series of polygons. Binding tasks were: Phonological Binding in which they had to match nonwords to non-speech sounds. In Visual–Spatial Binding they had to put polygons that they had seen in a grid, to the right position in it. In Cross-Modal binding students saw a polygon and a nonword and produced the corresponding nonword. The means for Visuospatial factor were lower indyslexic than in non-dyslexic pupils because of differences in language and non-verbal intelligence skills but even when non-verbal intelligence and language were taken into consideration, difficulties in the Phonological and Central Executive factors persisted.

De Carvalho et al.,2014 created two groups of children, one with dyslexia and the other without dyslexia, with ages ranging from 8 to 15 years old. Among the phonological components processed, the working and short-term memories were evaluated by a Digit Span task for which the WISC-III was used, that involved recurrence of digit series in both reverse and direct order, and tasks involving the recurrence of pseudowords. Values of the rate and accuracy factors during oral reading of words, pseudowords, and texts were studied in order to evaluate the decoding process. Protocol A, that includes narrative passages targeted for children aged 8 to 9 and 11 months and Protocol B, that contains narrative passages intended for children aged 10 and up were used for reading comprehension evaluation. In every text there are open questions for different types of cognitive processes evaluating. Next, questions concerning an oral story were used to gauge listening comprehension so as to achieve an improvement in understanding of reading comprehension. According to the results dyslexic students performed worse in the parameters of reading fluency as predicted and phonological short-term memory when testing their ability to repeat pseudowords, characterizing the phonological nature of the disorder.

Albano et al.,2016tested children with dyslexia and children whose reading abilities were within a normal range, from fourth to sixth grade for their visual-phonological binding. A nonword reading task was applied for Reading decoding (speed and accuracy). Visual-phonological memory binding task was used and contained stimuli consisting of 8 shape-nonword pairs. The monosyllabic nonwords were heard orally. Each of the 4 trials they participated in, included the same 8 pairs of shapes and nonwords and they had to remember the combination a shape and a nonword that was the same throughout the trials and among childrens. In all trials fifty percent of the shapes stayed in the same positions, while the other fifty percent had their positions altered. The study identified that dyslexic students had deficits in cross-modal memory binding andthey couldn't take advantage of the spatial locations to bind information as control students could do it. Also dyslexic students made phonological and binding errors more often than control students.

Rose & Rouhani, 2012 evaluated connected-text oral reading fluency for adolescents with dyslexia using Gray Oral Reading Test (GORT), 3rd Edition which asked students to read verbally a series of passages with increasing degree of difficulty. GORT assess the oral reading rate, word accuracy and comprehension. Also they measured those student's word-level skills by the Word Attack and Word Identification subtests of the Woodcock Reading Mastery Test. Word Identification subtest asked participants to distinguish regular and irregular words. In Word Attack subtest regular non-words are pronounced phonetically for testing of the capability to use grapheme–phoneme rules correctly. Oral language proficiency was examined employing the Peabody Picture Vocabulary Test, 3rd Edition. Multiple subtests of the WISC-III were also used. The performance scale was used for nonverbal intelligence evaluation. The vocabulary and digit span (combined) subtests were applied for expressive vocabulary and verbal W.M. assessment, respectively. According to the results many of childhood dyslexia main deficits persist in adolescence although the type of the correlations between cognitive and linguist predictors (i.e., word reading, vocabulary, and W.M) and oral reading fluency differs in dyslexic adolescents Specially W.M interacting with the vocabulary knowledge have an increased importance as predictors of oral reading fluency in dyslexic adolescents.

Giovagnoli et al., 2016 studied the visual-spatial abilities in elementary school children and children and teenagers in secondary school with and without developmental dyslexia. For the evaluation of visual-spacial perception abilities a more-local visual-spatial test (VPT2) and a more-global visual-perceptual test (VPT4) were used. Visual-spatial imagery and mental rotation abilities were assessed via the Spatial Rotation Test (SRT) and the STICK. Selective visual-spatial attention was rated with a subtest of the Test of Everyday Attention for Children (Map Mission, MAP). Integration of visual input and motor output was evaluated by the Visual Motor Integration Test(VMI). The younger children with developmental dyslexia had a significantly lower performance than normal readers in SRT,VPT2,VPT4 and VMI which demonstrate deficits in visual-spatial abilities that could negatively affect their reading skills. Their lower scores in VMI means inferior ability and/or lack of the required experience in handwriting. Also VMI significantly predicted their reading ability. The older students with developmental dyslexia showed deficits in VPT4 that could predict their reading performance, in SRT and in MAP. The younger students with developmental dyslexia demonstrated noticeably inferior performance in comparison to the older students in VPT2, STICK and SRT which proves that in initial phase of education more complicated and widespread visual-spatial deficiencies may impinge on studying letters and words, while subsequent phase of education more-global perceptual deficiencies may impede their reading process.

Maehler & Schuchardt, 2011 assessed the central executive functioning for students with dyslexia with normal IQ and lower IQ and for students with ordinary academic performance and normal IQ. In Backward digit and word span tasks the students had to recall in reverse order sequences of items presented to them. In double span task the students were required simultaneously a set of images by orally recoding the semantic content (phonological requirement) and their position (visual–spatial requirement) in the sequence they had seen them. Thus the students' capacity to synchronize the phonological loop's and visual-spatial sketchpad's functions was investigated. By the complex counting span task storage and processing childrens' ability were examined. The children saw yellow circles (goal objects) and squares (distractor objects) in random maps produced by computers. They had to determine and remember how many circles there were on each map. The data analysis showed that dyslexic children had deficits in central executive.

Dyscalculia and working memory deficits

Mammarella et al., 2015 compared visual and verbal W.M. function in students with developmental dyscalculia (DD) and typically developing students (TD) 11–13years-oldby using of two a computerized tasks. In the Backward words task for verbal WM was requested the recalling of two- and three-syllable words in reverse order that were presented verbally to students, to evaluate the competence to retain and use correctly verbal information. In Backward matrices task for visuospatial WM, students had to hold in memory and recall in reverse order the locations of blue cells that momentarily appeared in various locations on the screen, for assessing the ability to retain and use visuospatial information correctly. The students with DD didn't have deficits on verbal WM, but had specific deficits in the visuospatial WM. Researchers emphasized that these results were consistent with previous studies indicating a distinction in visuospatial WM between children with DD and TD and in particular students with DD presented specific deficiency in visuospatial W.M.

Szucs et al., 2013 compared the neuroscience theories and behavioral research theories about the causes of DD.The Listening Span task for verbal WM and the Odd One Out (OOO) task for visuo-spatial WM were used in primary school children. Spatial processing was assessed via a spatial symmetry task and a mental rotation task. For inhibition performance detecting numerical and non-numerical congruency effects in 4 experiments and with a Stop-signal task were used. It was found impaired visuo-spatial WM and inhibition function in students with DD. Researchers suggested that visuo-spatial WM dysfunction and the inhibitory function impairment are interrelated and the inhibition function impairment is correlated with the disturbance of central executive memory function. Spatial processing wasn't impaired.

Attout & Majerus,2015 investigated the verbal WM storage capacities in children aged 8-12 years with DD. WM for item information was examined by a nonword delayed repetition task in which pupils repeated monosyllabic nonwords. WM for serial order information was evaluated via a serial order reconstruction task in which students rearranged cards depicting the animals based on the order of their oral presentation. Mathematical skills were evaluated using a simple calculation task with a paper-and-pencil test in which they solved calculations for the 4 basic arithmetic operations and with the 4 operations mixed. The ordinal and magnitude judgment tasks were performed with symbolic/nonsymbolic quantities using E-Prime 2.0 software. For general nonverbal reasoning abilities Raven's Colored Progressive Matrices and for receptive vocabulary knowledge the Echelle de Vocabulaire en Images Peabody scales were used. Reading capacities were examined by the LUM subtest of the LMC-R battery and the L3 subtest of the ORLEC battery. Students with DD showed significantly reduced capacities to the maintaining of serial order information while performed no deficits to the maintaining of item information .The serial order WM deficit was accompanied by less efficient numerical ordinal processing capacities which means wider-ranging problems in ordinal information explicit processing.

Van Luit & Toll, 2018measured the frequency of deficits in W.M in students 8–18 years old with DD. W.M. was evaluated by using of Automated W.M. Assessment that included subtests consisted of blocks containing six trials. Verbal W.M. was assessed with the "Listening recall" subtest in which students after hearing a set of spoken sentences and at the end of everysethad to recognize if the sentence was true or false and remember the final word of every sentence in sequence. Visuospatial W.M. was measured by using of subtest "Odd one out". Students had to determine which of the three shapes they saw in adjacent boxes was different from the others. After every attempt, the student had to determine the position of each shape that stood out, in the right order. This study found that W.M deficits were diagnosed with the second highest frequency in children with DD.

Vashistha & Bapte, 2016choose a sample of 40 Dyscalculic students from classes 6-8 in order to investigate the Dyscalculics' Executive Functioning that has a significant connect with Mathematics ability and the effect of their low W.M.on Executive Functioning that they have. Dyscalculic Identification Scale was used to diagnose students with dysculculia. The self-constructed tool of Executive functioning was applied to Dyscalculics students for examining of Executive Functioning which consists of dimensions of Executive functioning namely: Concept Formation, Verbal fluency, Organization, Visuo-spatial processing, Planning, Inhibition, Cognitive flexibility. Findings that were existed in regard to the effect of the Predictive variable W.M on the Criterion variable Executive functioning. The results showed that W.M. has a strong effect on Dyscalculics' Executive functioning.

Attout et al.,2015 investigated WM abilities in adults with DD who had either finished or started their university education. Their mental and written calculation skills with the 4 fundamental operations as well as for fractions and decimals were examined by a test. Atest evaluating specifically their mental calculation was used. WM for order information was examined by a serial order reconstruction task in which progressively longer digit lists, were presented aurally. WM for item information was evaluated via a single monosyllabic nonword delayed repetition task. Nonverbal IQ by Standard Progressive Matrices test, verbal IQ by E.V.I.P. test, reading abilities by Alouette-R test, Nonwords reading and processing speed were investigated. This study found that adults with DD have a specific and persistent deficit WM for serial order information and they have persisting difficulties in arithmetic processing.

Kuhn et al.,2016 measured the W.M.in elementary school children with DD and/or attention-deficit/hyperactivity disorder (ADHD) and in typically developing children. Students took a part in a visual matrix span (MS) task to evaluate processes that tax the central executive and the visuospatial sketchpad. A necessary condition for participants in order to complete the task was to recall where each dot was located of a series of dots that they saw in a matrix on screen. Also a verbal span task (VS) was used for accessing students' storage and processing. They needed to remember a set of words displayed concurrently on the screen in order to meet task requirements. According to the results children with DD presented the lower performance on verbal and spatial W.M tasks which means they have deficits in W.M.

Maehler& Schuchardt, 2016used W.M. tasks for primary school children with and without learning disorders. Phonological tasks: In digit span task a series digits was presented acoustically that students had to repeat in the right display order. The same procedure was followed in one- and three-syllable word and nonword span tasks. In images span task students had to recall verbally the right presentation order of objects. In nonword repetition task they had to repeat the displayed word-like nonwords. Visual-spatial tasks: In location span task students might to remember the right positions for increasing sequences of dots. In Corsi-block a series of blocks that are fastened at random places on a board are tapped by the experimenter. Students tried to repeat the taps sequence in the right order. In matrix span task they had to reproduce patterns of boxes that appeared in a matrix. Central executive tasks: In backward digit and word span tasks the same items and procedures asprevious spans were used but recall of items sequences in reverse order was required. In double span task the identical pictures were shown as those used in the images span task, however were arranged differently on a matrix and pupils might remember the picture and their position in right presentation order for evaluating to what extent they can coordinate the functions of phonological loop and visual-spatial sketchpad. In complex counting span task students might remember how many circles appeared on each map they saw,for measuring of their storage and processing efficiency. It was found that students with dyscalculia have impairment in visual-spatial sketchpad of W.M.

Cowan & Powell,2014investigated the effect of domain-general (W.M, reasoning, processing speed, and oral language) and numerical factors (single-digit processing efficiency and multidigit skills) to significant arithmetic skills for third grade children as well as their role in mathematical learning disability (MLD or dyscalculia) and lesser number difficulty. For central executive assessment they used a subtest of the W.M. Test Battery for Children (WMTB-C) the Listening Recall. The results showed that students with dyscalculia have an impairment in central executive.

Difficulties in Physics understanding in dyslexia and dyscalculia

Trna & Pavlickova,2014 explained that students with dyslexia and dyscalculia present problems in physics learning. Students with dyslexia read slowly and struggle to understand a text, so they need more time to read a text and extract information from it. Their performance in solving learning tasks is reduced due to incorrect reading or improper understanding. Learners may find it difficult to comprehend the symbolic notation. Visual perception, very often visual differentiation that is the ability to distinguish figures and backgrounds, distinguish laterally inverted shapes and minutiae and perceive color, is impaired. Students with impaired visual perception, right-left and spatial orientation make mistakes in simple calculations because they skip digits, confuse their order in numbers, change position in the numbers when placing them one below the other, when writing fractions or decimal numbers. They also make changes to algorithms. Students with dyscalculia have reduced ability to match a number with the quantity of items, they don't understand satisfactorily the difference between geometric shapes. They present deficit orientation in arithmetic sequences, have problems in labeling of operation signs and mathematical operations, difficulties to read mathematical symbols and write them in dictation or transcription, decreased ability to do maths operations and assimilate maths relationships.

Trna et al., 2010 chose a student with dyscalculia and observed his development in solving of physics learning task from the age of 13 to the age of 15. Examples of such tasks was to calculate the lifting force which upholds a body with determinate volume in air when he was in the eighth grade, the accumulated heat of an iron body with a mass of 540 g and temperature of 15 ^oC was placed into a heating oven of 600 ^oC when he was in early ninth grade, the heat that a body loses when its temperature is decreased from 90^oC to 25 ^oC and the work produced by a lift track that take up a box of mass 300 kg to height of 2m when he was in late ninth grade. The student faced difficulties in arithmetic and in physics units conversion. He presented problems in data processing, inability to remember and apply physics-mathematics concepts, rules and formulas, difficulties with self-reflection of the solving of a physics learning task. Also he couldn't explain the solution of a learning task.

Ferentinou et al., 2009recorded a student's performance in physics who was diagnosed with problems in reading, writing with many orthographic errors, achieving an objective, social functionalism, lack of ingenuity in carrying out his activities. He attended the second grade high school and then the resource room. His teachers pointed out that he had difficulties in algebraic operations running, in solving difficult equations, in writing, in oral expression and in reading. He attended the physics lesson for the physical phenomenon of movement, concepts of force, pressure and energy in the mainstream physics class. He couldn't draw correctly the vector of a force exerted on an object nor understand the difference between contact forces and forces at a distance. In the physics resource room he was taught the concept of energy and specifically the definition of work, produced work by a constant force, kinetic energy and gravitational potential energy by using conceptual maps and the concept of pressure and specifically atmospheric pressure, Pascal's law and flotation without using of conceptual maps. He couldn't know concept of pressure like Pascal's law Torricelli's experiment, actors affecting the atmospheric pressure he couldn't understand the flotation and sinking a body and he was unable to apply the Pascal's law. He braved difficulties in running algebraic operations using the formula of kinetic energy for physics problem solving. In addition he didn't write the units of measurement either with the method of concept maps or without them.

Papalexopoulos et. al,2008identified the difficulties encountered by the adolescents students with dyslexia who were attending 10th and 11th grade, in reading and understanding the physics texts. Researchers assessed students comprehension of existing physics textbook without writing criteria application for the construction of physics texts accessible to dyslexic students, through their answers to relevant questions of this textbook. The questions were about recognition of physical phenomena, physical quantities, relations between the physical quantities, units of physical quantities measurement. Students with dyslexia in comparison to students without dyslexia had difficulties to recognize correctly physical phenomena, physical quantities, relations between the physical quantities, units of physical quantities measurement of the text included in the existing physics textbook.

Brigham et al.,2011note that students with SLD may face problems in learning science that result directly from their main characteristics but also from other factors that may be secondary or tertiary difficulties. The "root" issues that cause the SLD are the main characteristics. Maladaptive reactions to environment requirements because of the root issues lead to secondary and tertiary difficulties. They mention that according to 34 Code of Federal Regulations SLD defined as "a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, that may´ manifest itself in an imperfect ability to listen, think, speak, read, write, spell, or do mathematical calculations". Because of these primary problems they will have a reduced ability to absorb the knowledge offered in lectures, class discussions, textbooks, and media presentations. Besides, Maths is a frequent tool for solving physics subjects, so students will struggle to work with numeric data which is indissolubly linked to the understanding of science. Difficulties in spoken or written expression are an obstacle for students to demonstrate their true abilities. In addition they have problems with memory and recall information.

Trott ,2012profiled a dyslexic physics student's difficulties. He had slow processing speed and poor W.M. He was evaluated that write at a pace that was in the population's fifth percentile. He dealt with the tasks holistically, working in a non-sequential manner as a result of his intuitive sense for a situation. Because of this, he always found non-standard solutions and he didn't documented fully the methods he was using. Also he was imprecise and prone to mistakes. For example when he was undertaking integration by parts of cosh h cos h with respect to h. When he wrote down 2 functions which were similar he made mistakes in both writing and presenting the solution. However, he was very explicit about the nature of the problem and its solution. He copied wrong and instead of cosh wrote cosh h and vice versa. His written submissions lacked a logical order, flow or coherence and he often made a copy mistake during transferring between media, pages or lines. Because of his understanding of the problems at hand he was able to "see" the potential for solution. Because he had poor W.M., researcher emphasized that notations increase the load on W.M because students had to recall a wide range of standard notations and to be able to link symbol, word and process. Frequently, they must also keep in mind all aspects of a problem and several partial solutions some of which dyslexic students forget or overlook so they can't reach to the problem solution. Also the rote learning and rote recall of important definitions and theorems are a problem for dyslexic students.

Oginni &Olugbuyi,2014pointed out that students with dyslexia have difficulty reading and understanding the language of mathematics This difficulty affects their scientific and mathematical abilities. Dyscalculia appears as a difficulty in learning of basic mathematics. It is one of the most important factors that reflect negatively on learning sciences and mathematics in secondary education, and by extension prevents the student from manipulating numbers as well as solving math and science problems. Mathematics language is a basic prerequisite for sciences and mathematics teaching and learning. Dyslexic students find it difficult to manage the specific vocabulary related to quantities and spatial placement. These contain words and phrases whose meaning in the language of science and mathematics is difficult for students with dyslexia to understand. Also students with dyslexia and dyscalculia tension, helplessness, mental disorganization, and dread when they have to manipulate numbers and shapes and solve scientific and mathematic problems. Word problems are the heart of science subjects but dyslexia and dyscalculia causes ambiguity.

Cauchi, 2019 emphasized that Physics at school requires solving problems, practical hands-on experiments, but also the use of mathematics to find the values of physical quantities. Students with dyslexia confront many difficulties in physics because first of all they have to read and write definitions, laws and theories that they must understand. They tend to get distracted very easily with the result that they have difficulty understanding concepts that require full attention and concentration. Also students with dyslexia lag behind in laboratory and field work that are an integral part of science because they must give heed to teacher's explanations, recall instructions, record results and organize their time so that they can respond . Furthermore dyslexic students display a negativity in writing practical reports.

Discussion

Physics is a complex academic domain to learn (Träff et al.,2019; Uden et al., 2023)and requires various cognitive skills. Students have to grasp the meaning of scientific concepts related to learning about abstract scientific facts, theories, and laws. Also they are asked to develop scientific reasoning skills related to the ability to learn and apply complex scientific methods such as hypothesis generation, experimentation, and evidence assessment. So for a student to be able to learn the complex and abstract content of science, it is necessary to have the ability to use logic and abstract thinking (Träff et al., 2019).

Physics is an intellectually demanding subject that systematically challenges students because a prerequisite for coping it, is to combine learning with recall of content knowledge as well as acquire problem-solving skills. Curricula and assessments often target "learning as understanding". Based on this criterion the ability to access content knowledge is necessary but it is not enough to ensure successful learning. Physics requires the ability to think and solve problems. Thus, in order to learn physics, students should acquire knowledge that will be accessible and also they will be able to use it. Consequently, students who memorize physics elements without understanding their meaning or context encounter great difficulties in applying their knowledge in problem solving(Bartley, 2018). Physics problem solving requires conceptual understanding combined with appropriate mathematical and reasoning skills (Tsigaridis et al.,2022).So physics learning is based on learning to select and then apply content knowledge (facts, theories, ideas} using critical thought (Bartley, 2018).

Abstract scientific phenomena and concepts are analyzed and explained using many types of representations such as experiments, diagrams, graphical representations such as line graphs, physical models, mathematical symbols, numbers with units, elements of geometry like rays and arrows, formulas ,functions , equations and calculations (Träff et al., 2019; Uden et al.,2023; Umaru & Salau, 2019; Pospiech et al.,2019). Students must consolidate and learn how these representations are transformed into one another(Uden et al.,2023). The use of knowledge of geometry and trigonometry is necessary to solve many physics problems. For example, the diagrams drawn for the analysis of the force exerted on an object in its components and the calculation of its direction require knowledge of geometry and trigonometry(Chen et al.,2021). Also in the evaluation of experiments, line graphs are used, with the help of which the data that have been recorded and entered in tables are visualized. Thus, these graphs serve as a bridge between an experiment or phenomenon and the algebraic formulation of a physical law (Pospiech et al., 2019).

Algebraic representations, i.e. formulas, equations and functions, condense physical information using symbols based on specific conventions. With these conventions, physical information is recognized, acquired and used by those who deal with physics, with the assumption that they know the symbols, the meaning of the symbols and the concept of the physical quantities that are represented. Formulas are algebraic terms with a physical meaning where each symbol expresses a physical quantity and concepts or defines new physical quantities. Using formulas we calculate specific values of quantities and make precise quantitative predictions which are evaluated and verified (Pospiech et al., 2019).The computational ability of mathematics is the most direct and frequent operation in physics. Also with the help of mathematical function simplification skills, students can simplify a lot physical formulas, find new formulas and place specific physical values and make calculations(Chen et al.,2021). Function in physics aims at functional thinking, perceiving and using the simultaneous change of quantities. Line graphs are essentialbecause they give a broad picture of the function as a whole. When a formula is considered as a function, we must identify the dependent and independent variables, find the constant parameters, and after the dependence relationships of the variables and the mathematical techniques are identified, it can lead to more knowledge about physical phenomena (Pospiech et al.,2019).

The interpretation and understanding of physical models of graphical representations and diagrams that are forms of visual-spatial representations require spatial processing abilities. Spatial processing functions, like creating spatial-schematic images of abstract concepts and making spatial transformations of these mental images, are used for science problem solving. The creation of spatial transformations assumes the capacity to mentally rotate images, to link or correlate various elements of visual-spatial information, and to separate images into discrete pieces in order to analyze each one particularly. So science is a demanding field that requires a combination of reading/language work, comprehension procedures (logical reasoning) and visual-spatial analyses. This means that a flexible and effective mental workplace capable of guiding, coordinating and carrying out all the necessary procedures for solving physics problems must be available. According to the researchers, W.M is a fundamental achievement factor of scientific reasoning (Träff et al.,2019).

The phonological loop guides the learning of new spoken or written words through overt naming, and reading ability depends on its operation speed(Brooks et al.,2011) as well as has a decisive role in understanding and solving of arithmetical word problems(Cockcroft, 2015). Patients with phonological loop deficits have major problems in acquiring new vocabulary (Baddeley, 2000).Visual-spatial sketchpad affects every day reading tasks, where it possibly plays an important role in preserving a representation of the page and its layout which will not be changed and facilitates tasks like moving the eyes precisely from the end of one line to the start of the next. In addition the researchers suggest that cognitive faculties and the capability to maintain and manipulate visuospatial information is likely to have a significant effect on language comprehension, at least in the case of certain types of material(Baddeley, 2003)on learning numbers and interpreting graphs. Phonological loop and visualspatial sketchpad are both involved in counting and mental arithmetic while different mechanisms of visualspatial sketchpad affect the mathematical calculations ability according to age(Cockcroft, 2015). Central executive is able to co-ordinate information from the two slave systems. It is able to control and manipulate information stored in the phonological loop and visuospatial sketchpad (Pham& Hasson, 2014). In solving novel problems, reading comprehension, conceptual development, multistep arithmetical problems the central executive is mostly involved(Cockcroft, 2015).

According to research, learning is constrained from the limits of W.M. W.M represents a cognitive ability that is linked to academic success. This is due to the fact that W.M is closely linked to fluid intelligence which is related to reasoning, processing speed and novel problem solving ability. Because of this relationship, good W.M. implies increased problem-solving ability. Fluid intelligence and W.M. together facilitate the new learning. Because children with reduced memory capacity when they have to deal with difficult cognitive tasks have a tendency to 'zone out' or mentally stray from the task they are often thought to have attention problems. Problems in maintaining attention are due to an overloaded W.M. that can't maintain the information necessary to carry out a continuing mental task. So they often can't follow instructions or give up on tasks quickly. Also, children with low W.M expend more effort on complex tasks that require simultaneous processing such as retaining multi-part instructions or attending complex tasks such as listening and writing. Ergo children with poor W.M. may permanently "miss" crucial information necessary for acquiring knowledge and skills in important academic fields like mathematics and science. Also if they can't correctly bring back information from long-term memory to support that which is maintained in W.M. they may have trouble updating or renewing information in memory. Consequently, these children struggle to choose and integrate relevant information in a specific scientific area. If there is even a little bit of irrelevant information in a task, children with low W.M. they may have difficulty isolating or blocking it, which has consequence the W.M. overloading. Also children with low W.M. may struggle to achieve mental shifting between concepts and information for example, in mathematics, where switching between mathematical processes is needed to perform multy-digit mathematical operations(Cockcroft, 2015).

Conclusion

Three conclusions emerge from present study. First, dyslexia and dyscalculia are due to deficits in the phonological loop, in the visuospatial sketchpad and central executive of WM.. Second, students with dyslexia or/and dyscalculia show weakness in the cognitive skills necessary for understanding about abstract scientific facts, theories and laws of Physics as well as their application in physics problem solving. Thirdly, for these cognitive skills it is proven that the phonological loop, the visuospatial sketch and the central executive are responsible. So we conclude that people with dyslexia or/and dyscalculia present an additional specific learning disability in the science of Physics which is due to phonological loop, visuospatial sketch and central executive impairments . For this specific learning disability we introduce the term dysphysics. Future research should focus on dysphysics in order to find ways to deal with this special learning disability.

Recommendations

Students to successfully meet the demands of Physics will need to combine learning with recall of content knowledge as well as acquire problem-solving skills. Also, solving physics problems requires conceptual understanding combined with appropriate mathematical and reasoning skills. Working memory is a determining factor that leads to the scientific reasoning necessary for Physics. People with dyslexia or /and dyscalculia because they have deficits in working memory face difficulties in understanding of physics and in solving physics problems. Therefore, physics teachers should acquire training for the type of difficulties these individuals have in Physics and the involvement of working memory deficits in these difficulties. It is also necessary to create tools to strengthen these individuals' the working memory and the use of these tools by teachers.

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