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Intervention programs aimed at the improvement of Working Memory

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Abstract

The contribution of working memory both in the educational process and in our everyday life is considered very important and is widely accepted by the scientific community. Working memory is what helps humans to retain information and mentally perform a series of actions. This paper examines working memory in people with dyslexia and dyscalculia. The aim of the paper is to suggest ways to improve working memory as a method of intervention for children with dyslexia and dyscalculia using ICT.

Keywords: Dyscalculia; Dyslexia; ICTs; Working Memory; Intervention

1. Introduction

It is widely accepted by the scientific community that working memory is closely linked to the learning process as before knowledge can be consolidated, we must first retain a volume of information, process it and decide which information to keep and which not to keep, so that it can be stored in the long term memory. All of the above is performed by working memory, as through the sensory organs, it is the first recipient of information [1].

Learning in itself as a process requires many complex processes, such as performing an action and, at the same time, retaining all the instructions to complete a task. Such a cognitive process is very difficult or even impossible in the cases of children with working memory deficits, not because they cannot succeed if they are given the instructions separately, but because of the overload of working memory [1].

A typical case of the phenomenon just described above is children with dyslexia. The dyslexic student, although having a normal intellectual potential, nevertheless fails. The causes are many and one of them is limited working memory. Its importance can be seen in its consequences because overall the student with deficient working memory performs poorly. Common characteristics are that his attention is easily distracted, he does not participate in group work because he cannot retain what he has to do, he does not raise his hand in class because by the time he answers the question he has forgotten it, he does not complete the tasks but leaves them in the middle since he doesn't remember the continuation [1].

The situation is similar for pupils with dyscalculia. Research shows that working memory is essential for mathematical skills [1]–[3]. Students with dyscalculia have low performance in sequential repetition, they cannot retain information and repeat it in a specific order [4], [5]. They also have poor visual-spatial working memory, which plays an important role in cognitive, neurobiological, and developmental patterns of formal and informal mathematical skills (Menon, 2016).

This paper examines online educational intervention programs aimed at improving working memory in children with dyslexia and/ or dyscalculia.

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2. Intervention programs

The fact that children with learning disabilities or attention deficit disorder are affected by interference with working memory raises the question of whether working memory can be subjected to training. For a long time, the prevailing view was that memory performance could only be enhanced through knowledge accumulation, through mnemonic strategies and metacognitive control. Attempts to improve working memory capacity through simple repetitive practice to automate knowledge have not proven very successful.

Meanwhile, research on working memory training is in full swing, as recognition of the importance of working memory to children's performance and overall school achievement has intensified efforts to specifically promote this area of cognitive functions. Recently published studies showed that adopted training had a positive effect on children with learning disabilities (and functional memory deficits) [6], [7]. These studies differ significantly in terms of the respective aims of their interventions. Often, the emphasis is on training methods that aim to optimize the central processor, rather than the phonological circuit or the visual-spatial sketchpad.

The latest trend in efforts to improve cognitive abilities is the use of computer-based training programs that aim to improve working memory and strengthen its function through the practice of tasks that activate it. The research area of cognitive training using targeted educational software is an area that is constantly developing [8]–[34]. In recent years, educational programs have also emerged and have moved up a level as they use AI, STEM & ROBOTICS [35]–[39].

A touchscreen computer as an educational device seems to be particularly attractive to children, thus promoting their motivation to participate in education [40]–[43].

3. For students with dyslexia

Dyslexia is the most common learning disability and is characterized by low reading skills in children who have adequate intelligence, formal education and adequate sociocultural opportunities [44], [45]. Many studies have shown that children with dyslexia benefit from early intervention programs that focus on phonological, orthographic or morphological spelling [46]–[49]. However, some children do not respond to such programs. Other studies have examined whether dyslexia involves deficits in working memory subsystems such as the phonological loop, the visual-spatial sketchpad, and the central executive [50]–[53].

The development of reading and spelling skills in students with dyslexia, by definition, is delayed and often lags despite years of instruction. Three qualities are thought to facilitate reading development in these children: the provision of a highly structured phonics curriculum with a strong emphasis on the alphabetic system, repetition to compensate for short-term verbal memory deficits, and multisensory methods to promote non-linguistic mental representations. Learning objectives should be sequential because the logic of language structures can escape children with dyslexia. Comprehension and metacognitive processes must be taught to assist these students in the conscious use of language rule systems to guide their reading and spelling.

Amirs Shiran and Zvia Breznitz (2010) examined whether dyslexic readers' recall and process speed in working memory can be increased by improving the quality of their reading. 91 native Jewish middle-class students participated in the study, including 41 dyslexics and 50 skilled readers. Participants were divided into four groups. Thirty-five skilled readers and twenty-six dyslexic readers were trained in the area of working memory and compared to control groups of fifteen skilled and fifteen dyslexic readers who completed a stand-alone reading training program. All training lasted six weeks. Indicators of reading and working memory were collected before and after the two training sessions [54].

The program used for the present study was CogniFit Personal Coach (Cognifit, 2003), a computer program for adults that aimed at training three different modules of working memory:

Auditory short-term memory and processing of verbal and non-verbal information that are located in the auditory channel.

Visual verbal short-term memory and processing of verbal information that are located in the visual channel.

Visual-spatial short-term memory of visual patterns and their spatial location [54].

The results after working memory training showed that the ability to store verbal and visual-spatial information in working memory increased, decoding, reading rate, and comprehension rate improved in both groups, although the gap between the two groups, dyslexic and control groups in reading and working memory remained stable [54].

Luo et al, in a 2013 study, took thirty dyslexic children aged 8-11 years and proceeded to educate them. The training took place in a primary school in Wuhan, Hubei Province, China. The thirty dyslexic children were randomly divided into a treatment group (11 boys and 4 girls) and a control group (10 boys and 5 girls). The treatment group trained for 40 minutes per day and with an adjusted level of difficulty. The control group was trained for 10 minutes per day, but the level of difficulty level was not interactively adjusted. All of them participated in a 5-week training program. [45].

During the week before the start of training, participants completed a series of assessments of working memory performance and reading achievement. Reading-related skills in the control group were measured within the same time interval as the treatment group. The format of the training was tailored for each individual. All children completed two assessment sessions within the same time intervals: pre-test, and post-test 5–6 weeks [45].

Children in the treatment group participated using a computerized gaming environment. This training took place for approximately 40 minutes a day at school for a period of 5 weeks. Children completed 100-150 trials each day. According to Torkel Klingberg's experimental design (Klingberg, et al, 2002), the control group trained with a “placebo” or “low dose” computer program that was similar to the treatment program, except that the level of difficulty was not interactively adjusted and daily training was less than 10 min [45].

Results from baseline and post-training tests in the treatment group were compared to the control group, which received a low-dose version of the training. This comparison showed that training did indeed improve children's working memory. Increased performance was observed in untrained areas of working memory, visual-spatial sketchpad, and central executive, indicating that training effects generalized to other abilities. A significant effect of training was observed for both visual rhyming and reading fluency (one-minute word reading tests). These experimental findings suggest that working memory is a key factor in the reading of children with dyslexia, and interventions to improve working memory can help dyslexic children gain reading fluency [45].

For a child's future school performance in the area of language and numeracy, the functional efficiency of working memory is a central predictor. Children suffering from dyslexia show specific deficits in working memory functions. A software application for elementary school children has been specifically designed by Maehler, et al. (2019) to improve working memory function. Based on Baddeley's (1986) model of working memory, the phonological loop, visual-spatial sketchpad, and central executive were trained in 18 sessions over a six-week period. The group of subjects who participated in this training consisted of 139 third-grade students, of whom 43 were dyslexic and 27 were not. The control group consisted of 41 students with dyslexia and 28 without. The participants were divided into the following groups: dyslexia group (subgroups: DYS -T = trained dyslexia or DYS-UT = untrained dyslexia) and one of two control groups (CT = trained control group and C- UT = untrained) [55].

All children were given a preliminary test. The first measurement (pre-test) was taken at the beginning of the study to assess school performance, intelligence, and working memory capacity. Then, over six weeks, three weekly 45-minute training sessions were conducted. Post-test was conducted after the end of the training. Three months later, follow-up measurements were taken, once again recording working memory performance to determine the long-term effectiveness of the treatment [55].

The designers implemented an adaptive training program (AGENT 8-1-0) to improve both the ability and functional effectiveness of working memory. The AGENT 8-1-0 game consists of 18 training sessions (divided into three 45-minute sessions of three sessions per week over a six-week period). Each child sat in front of his or her screen, wore headphones, and worked separately on the tasks. This is necessary because the program follows an adaptive algorithm related to the individual level of working memory capacity. Research assistants accompanied each child at first, but then all instructions were given by the computer so that each child could proceed at his or her own pace. In each of the 18 training sessions, five tasks out of a total of ten were assigned. Two games aimed at improving the capacity of the phonological loop, one game to improve the visual-spatial memory and two games to stimulate the central executive, one containing phonological and one containing visual-spatial information [55].

Regarding dyslexia (comparison of dyslexic children with a control group), significant differences appeared in all areas of the phonological loop, as well as the central executive. While the short-term effects of the program could not be demonstrated, the present analyses focus on long-term effects for both dyslexic and typically developing children, i.e., whether educational effects can be sustained over a longer period or even after a certain period of time. The results obtained prior to testing/monitoring reveal that no long-term increase in performance in terms of phonological and central executive working memory can be confirmed. Findings document performance improvements for typical children in a visual-spatial sketchpad and central executive subsystems, while for children with dyslexia only the central executive. Unfortunately, and despite intensive training efforts, the results did not materialize for the phonological loop, a part of working memory that is critical for children with dyslexia [55].

4. For students with dyscalculia

The term "dyscalculia" was first introduced in 1940 to describe the numerical difficulties faced by students who did not have a low IQ or learning deficits but were unable to learn and understand mathematics [56]. Very often the term Learning Difficulties in Mathematics (L.D.M) is also used. The term Developmental Dyscalculia (D.D.) is used for core deficits; numerical abilities (e.g., difficulty in processing quantities) and a relatively specific behavioral dysfunction. In contrast, M.D.D. is caused by several cognitive deficits, such as inadequate working memory, visuospatial processing, or attention. Thus, the conditions D.D. and L.D.M. would manifest in different behaviors [57].

In 2013, Price and Ansari proposed the separation of developmental dyscalculia into primary and secondary. In primary developmental dyscalculia, they classified people who present severe mathematical difficulties, which are due to incomplete brain development. The incomplete development results in a reduced ability to process numerical quantities. On the other hand, in the secondary they classified other types of difficulties that may be due to working memory problems, attention problems, etc. [58].

Rourke (1994) carried out a variety of research and concluded that students with dyscalculia compared to children with special learning disabilities have a different cognitive and neuropsychological profiles. In addition, their education must be differentiated: children with dyscalculia must first be given a verbal description of the action, then students must learn to describe the action, and finally they must be given symbols and objects [59].

Students with dyscalculia have reduced capacity in their working memory based on research (Geary, 2004), Szucs and colleagues (2013) argued that the deficits are located in visuospatial working memory and visuospatial short-term memory [60]. Working memory problems along with anxiety reduce students' performance in mathematics which in turn affects students' self-esteem [61].

Castro, Bissaco, Panccioni, Rodrigues and Domingues conducted a study in which the initial sample included 100 students, between 7 and 10 years old. The children were given an assessment criterion on mathematics and the 26 students who performed the lowest were eventually included in the study. The children were randomly divided into two groups (experimental and control). The two groups received intervention, the experimental group with the help of the virtual environment through computer, while the second group received intervention through traditional methods. The teacher of the children in the experimental group noted that the students were able to participate more after the intervention was completed and also during the intervention. In general, their performance improved and they wanted to continue the activities because they had aroused their curiosity and were a motivation for learning. The intervention included games that helped students develop [62]:

- The working memory.
- The visuospatial perception
- Quantity representation using Arabic symbols
- Processing of continuous and discrete quantities
- Reading and writing numbers
- Development of the calculation process (execution of operations)
- Identification of measurable quantities

The University of Jordan in 2022 published an article presenting the results of a comprehensive intervention for students with dyscalculia based on working memory and the sketchnote technique. The sample included 60 third-grade students (aged 7 to 8 years), all diagnosed with dyscalculia. The students were divided into three groups (experimental A, experimental B and control group). Experimental group A participated in an intervention that included programs targeting working memory and the sketchnote technique, while B participated in the sketchnote technique only. The main objective was for the students to be able to solve word problems [63].

The sketchnote workshop consisted of four 40-minute sessions. In the first session there was an introduction to the sketchnote technique and an introduction to some symbols, in the second session examples of using sketchnote in number knowledge, comparison and number sequences, and in the last session solving of exercises [63].

The working memory intervention program consisted of 16, 30-minute sessions. In the sessions, students learned strategies (rehearsal, mental imagery, narrative strategy, visuospatial strategy, and encoding strategy), and ways to apply them.[63]

The findings of the study confirmed the contribution of working memory to the ability to solve mathematical word problems, attention enhancement and language processing. Sketchnote increases students' ability to solve verbal problems. The combination of the two techniques showed that 73.2% of students with dyscalculia improved their ability to solve word problems [63].

As mentioned earlier, students with special learning difficulties have deficits in working memory. An application that would coach these students and improve their working memory would also benefit their performance overall.

Nemmi and his colleagues created software that aimed to investigate whether educational programs can affect student performance of students in general, and also students with working memory deficits. A total of 259 students, aged 6 years old, participated in the study, of which 49 with working memory impairments [64].

All participants underwent diagnostic tests on working memory and mathematical abilities before and after the intervention. Participants were divided into 4 groups which were trained daily for 30 minutes for 8 weeks. Each group would receive a different intervention: WM training (WMT), number-line training (NLT), WMT and Reading, NLT and Reading or 100% Reading [64].

The WMT included activities targeting visual-spatial working memory. The NLT included activities in which the student had to drag his or her finger across a number line displayed on the screen to answer the questions asked. For example, students ware shown the number "5" and would have to drag their finger from zero to 5. The goal of these activities was to connect students between the Arabic symbol, spatial position, length and number of objects [64].

Students progressed to the next level when they completed the previous one, without being limited in time, and as the progressed the activities became more difficult. However the level of difficulty was adapted to the needs of each student [64].

The final results confirmed the usefulness of the number line for teaching mathematics. The WMT, however, seemed to benefit more students who already had high scores on WM activities. The combination of both techniques seemed to have the best effect across the population [64].

5. Discussion

Finally, the use of ICT tools in the educational process is very important both in general education [65] and special [11], [23], [29], [43], [56], [66]–[70], as they increase the motivation to learn. Several intervention programs focus on working memory using ICT such as Cogmed, CogniFit, Jungle Memory, Nback training and complex span training [71] and in combination with improving eating habits [72]–[75], the development of emotional intelligence, mindfulness and metacognitive skills [7], [70], [76]–[101]have a positive effect on students with learning difficulties. Important role play also the use of mobiles, AI, STEM, robotics and games [102-109]

6. Conclusion

Summarizing the research results from the literature review, it is concluded that working memory plays an important role in the knowledge acquisition of all students and is closely related to dyslexia and dyscalculia, as it has been scientifically documented that these children have a deficit in this area. So, in such cases, interventions with programs that reinforce memory are considered necessary because they greatly benefit the student. From the review of the intervention programs presented in the paper, it is seen that on the whole results of the intervention programs are positive. However, more efforts and more intervention programs with a larger sample are still needed.

Compliance with ethical standards

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Disclosure of conflict of interest

The Authors proclaim no conflict of interest.

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