International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 02 | Feb 2021 www.irjet.net p-ISSN: 2395-0072

# Gamification as a Remedy for Dyscalculia

**Vidhisha Singal[1], Snehal Bakre[2]**

[1]*Student, Computer Engineering Department, K. J. Somaiya Institute of Engineering and Information Technology, Mumbai, India*
[2]*Student, Computer Engineering Department, K. J. Somaiya Institute of Engineering and Information Technology, Mumbai, India*

---

**Abstract –** *Difficulty in understanding the concepts of mathematics is a type of learning disorder known as dyscalculia. Dyscalculia refers to various challenges dealing with math, i.e., from understanding numbers, a basic of mathematics, to the inability to remember the mathematical language. Identifying the signs of dyscalculia in a child at an earlier stage can be more effective in terms of improving the condition rather than identifying it at a later stage. Gamification is a process of providing a gaming platform for learning various concepts and evaluating the candidate based on its progress. It is found to be helpful for children suffering from dyscalculia. In this paper we have proposed a software named Math Warrior that works on three stages; the first stage which involves identifying whether the child shows any signs of dyscalculia or not, the second stage generates patterns associated with areas of weakness, and the last stage which provides a gamification-based remedy for children of 3-5 years of age. This software provides a comparative analysis in the form of a graph that shows the pattern of the child having dyscalculia compared with the pattern of all the other children using the software. Also, it evaluates them based on their performance while playing games with the help of a question-answer set. It also rewards the kids with points and badges thereby providing them a motivating platform. The software also allows the parents as well as teachers to constantly monitor the child's progress.*

***Key Words*: Dyscalculia, Gamification techniques, Math warrior, Learning disabilities, Comparative analysis, Educational games**

## 1.INTRODUCTION

The learning disabilities are broadly classified into three categories: Dyslexia (difficulty while processing the language), Dysgraphia (difficulty while writing), and Dyscalculia (difficulty while processing numbers). This paper discusses in detail about dyscalculia. The problems faced by the child in mathematics not only hampers the child's ability to do math but also affects the ability to do his/her daily tasks. For example, a dyscalculic child may find it difficult to relate a word five with its corresponding number 5. Therefore, it is important to understand the problem faced by the child in order to help it improve its condition. Various tools are developed to help the child in overcoming the fears of mathematics. Classroom learning evolved to e-learning. But both these methods are not up to the mark to help the child in dealing with the problem of dyscalculia. To help such students, gamification can be a powerful aid. Gamification helps to motivate the child to actively participate in the classroom activities because it makes the training fun and simple. Gamification is essentially the way humans learn. Understanding the participants, elucidating the learning objective, structuring the experience, keying out the resources, and implementing gamification elements are the five steps of gamification [1]. Studies have shown the recall rate for verbal information alone is 10% and knowledge retained through both verbal and its corresponding pictographic view is 90%. Hence, the knowledge gained with the help of games can be retained for a longer period of time [2]. The proposed software includes three levels of evaluation-

i. Evaluating whether the child shows any signs of dyscalculia.
ii. Extracting the pattern of the child signifying the areas of weakness.
iii. Providing remediation based on the areas of weakness.

## 2. BACKGROUND AND RELATED WORK

In order to understand the various topics involving dyscalculia, a step-by-step review of the same was performed. In order to facilitate the review procedure, the internet and also various reference books were explored, one of which was the WJ IV test manual that explains various tests which helped in deciding if the child has dyscalculia or not[3]. On the internet, various research papers, websites, journals, books were explored with the help of the following keywords- gamification, dyscalculia, learning disabilities, game-based learning, which basically helped us study dyscalculic children and in turn helped us in our research.

Each dyscalculic child has a different way of learning. They generally take more time to grasp concepts than a normal child. So, various studies and researches have been carried out to understand the problems associated with dyscalculia and provide remedies for the same. Of all the studies carried

out, some of them are mentioned below by categorizing them into three perspectives-

## 2.1 Understanding Dyscalculia From A Biological Perspective

https://dopasolution.com/dyscalculia Dyscalculia is categorized into various categories and various problems associated with it. [4]

https://www.understood.org The two main causes of dyscalculia are believed to be brain development, and genes and hereditary. [5]

Kadosh, R. C., Kadosh, K. C., & Henik, A., "When brightness counts: The neuronal correlate of numerical-luminance interference", Cerebral Cortex, 18(2), 337–343. A study has been carried out to find out which area of the brain is affected in dyscalculic. [6]

Cohen Kadosh, R., Cohen Kadosh, K., Schuhmann, T., Kaas, A., Goebel, R., Henik, A., & Sack, A. T., "Virtual dyscalculia induced by parietal-lobe TMS impairs automatic magnitude processing", 2007, Current Biology, 17(8), 689–693. Studies conducted on non-dyscalculic people have shown that the right intraparietal sulcus (IPS) is related to mathematical processing. The dyscalculic have an impaired IPS which is why their brain cannot process numbers efficiently. [7]

Antonia, P., Catherine, B., & Panayiotis, V., "Cognitive science: From molecular biology to brain function", 2015 6th International Conference on Information, Intelligence, Systems and Applications (IISA). A study has been carried out to find out the connection between neurons in the cerebral cortex and dyscalculia. [8]

## 2.2 Helping Teachers And Parents In Understanding Signs Of Dyscalculia

Filipa Ferraz, José Neves, "A brief look into dyscalculia and supportive tools", 2015 IEEE International Conference on E-Health and Bioengineering. A software called Dyscalculia Screener was designed for the teachers to evaluate whether a child has dyscalculia and identify the weak mathematical area of the child. [9]

Tahan, O., & Barake, F., "A gaming environment to train teachers diagnose children learning disabilities."2018 14th International Computer Engineering Conference (ICENCO). The software was developed to help teachers tell whether the decision taken for each dyscalculic child is correct or not. [10]

Aljowaysir, N., Ozdemir, T. O., & Kim, T., "Differentiated learning patterns with mixed reality", 2019 IEEE Games, Entertainment, Media Conference (GEM). Mixed Reality is a platform that allows teachers to engage students in learning the various concept of mathematics. [11]

## 2.3 Various Software Aids For Dyscalculic Children

**Table -1:** Available technological aids and their limitations

| Paper reference no. | Target category with age | Application | Future scope |
|---|---|---|---|
| [12] | 3-7 | Chocolator, a swift playground calculator | Can be extended to include other arithmetic operators like multiplication, division. |
| [13] | 8-9 | Web based tests, Dyscalc Test Environment | Adaptive test for each child to identify the area of weakness. |
| [9] | 6-9 | Dynamo Math | Provide remedies for improving the dyscalculic condition. |
| [14] | 11-18 | LudiMoodle | A better model that identifies the area of weakness. |
| [15] | 11-17 | Stanford Diagnostic Mathematics Test | Include remedies for the diagnosis. |
| [16] | 0-7 & 11-12 | Diagnostic Test Of Arithmetic Strategies | A Diagnostic test that can include other areas of math. |
| [17] | 0-8 & 11-17 | Test of Mathematical Abilities | Adaptive test and remedies based o test results. |
| [18] | 6-12 | Hudson Education Skills | Design a toolkit to identify the problem rather |

| | | | |
|---|---|---|---|
| | | Inventory-Math | than just steps in resolving it. |
| [19] | 3-8 | Test of Early Mathematics Ability | Provide solutions to help solve problems in areas of math. |
| [20] | 6-14 | Dyscalculia Screener | Provide students with all the help needed to solve subtraction and division. |

## 3. PROPOSED SYSTEM

As, gamification is found to be effective [21] this paper discusses the software Math Warrior which is implemented using the concepts of gamification. It provides evaluation, identification, and remedy for dyscalculia.

### 3.1 Major Components Of The Software

While developing the software various elements were considered, of which three were identified to be the major components of this software.

#### 3.1.1 Target Age Group
The software is developed for children of age 3 to 5 years.

#### 3.1.2 Questionnaire
A set of questions designed in such a way that will help identify whether the child shows any signs of dyscalculia or not.

#### 3.1.3 Interactive Test
A computer-based test is designed to extract a pattern that identifies the weak areas of the child. After identification of weak areas, an adaptive test is designed to track the progress of the child.

#### 3.1.4 Effective Learning Module
Games are designed in a way that will help the child to learn the concepts of mathematics and make him retain the concepts for a longer period of time.

### 3.2 Flow Of The Software

The software is divided into three phases-

#### 3.2.1 Determining Whether The Child Is Dyscalculic Or Not
Based on the answers provided by the parent/teacher of the child the software evaluates whether the child shows signs of dyscalculia or not.

#### 3.2.2 Pattern Extraction
Based on the answers provided by the child the software extracts a pattern i.e. the software identifies the area of weakness of the child.

#### 3.2.3 Remediation
On the basis of the pattern extracted, various games designed are displayed to the child so as to learn the concepts of weaker sections. If a satisfactory score is reached, the child is evaluated for its progress with the help of a test.

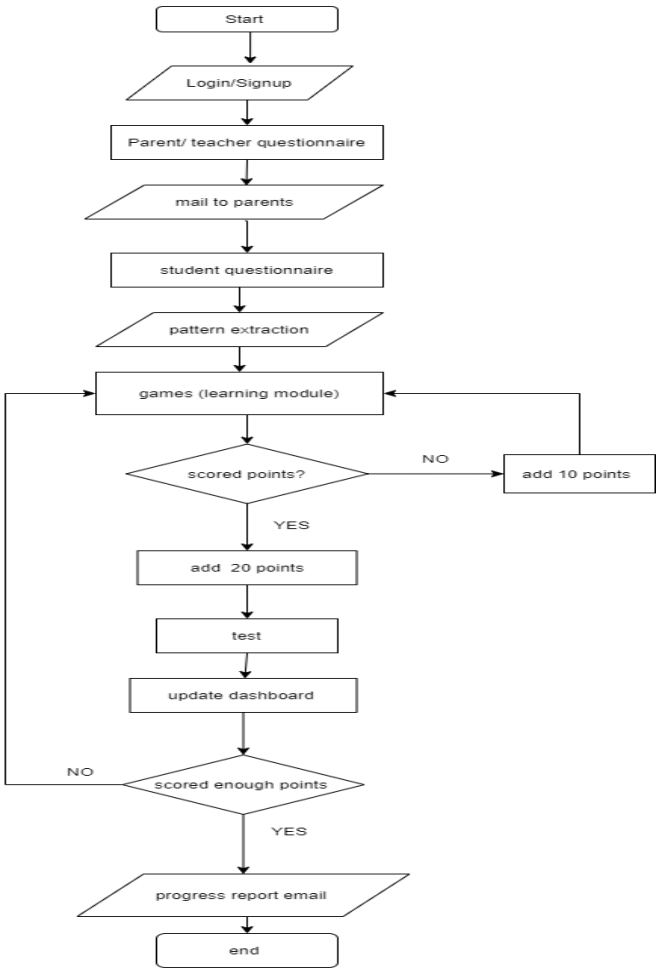


**Fig- 1:** Flowchart of the system

## 4. PHASES OF THE SOFTWARE

This section explains in detail the three phases of the software designed.

### 4.1 Determining

In this phase, a parent/teacher is provided with a set of five questions. These five questions serve as the basis to determine whether the child falls under the category of showing signs of dyscalculia or not. For every question, the parent/teacher is provided with three options: always, sometimes, or never. An algorithm is designed to determine whether the child shows any signs of dyscalculia or not. This algorithm forms clusters of the answers provided by parent/ teacher and then after performing computations on the clusters formed, it displays the desired results. The questionnaire is as follows:

**Table 2 -** Questions designed to check for signs of dyscalculia

| Question No | Question | Category |
|---|---|---|
| 1 | Is the child able to solve the numeracy questions:<br>- Make connection with words (Eg- four is 4)<br>- Recognize and write numbers | Number |
| 2 | Is the child able to tell the sequence | Sequence |
| 3 | If the child is able to count the objects. | Counting |
| 4 | Is the child able to perform comparing:<br>- Compare objects having contrasting behavior.<br>- Understand mathematical concepts such as greater than less than | Comparing |
| 5 | Is the child able to perform basic arithmetic operations:<br>- Being able to work with addition, subtraction.<br>- Recognize mathematical signs like +,-. | Calculation |

#### 4.1.1 Pseudo Code

```
if (number = always)
        Falls under the highest risk
else sort the data into three clusters.
1.      Clusters Always
2.      Cluster Sometimes
3.      Cluster never

if(len(cluster_always) > len(cluster_sometimes) and len(cluster_always) > len(cluster_never))
        Falls under highest risk

elif(len(cluster_sometimes) > len(cluster_always) and len(cluster_sometimes) > len(cluster_never))
        Falls under moderate risk

elif(len(cluster_never) > len(cluster_always) and len(cluster_never ) > len(cluster_sometimes))
        Falls under lowest risk

elif(len(cluster_always) == len(cluster_sometimes) and (len(cluster_always) > len(cluster_never) and len(cluster_sometimes) > len(cluster_never)))
        Falls under highest risk
elif(len(cluster_always) == len(cluster_never) and (len(cluster_always) > len(cluster_sometimes) and len(cluster_never) > len(cluster_sometimes))):
        Falls under moderate risk

elif(len(cluster_sometimes) == len(cluster_never) and (len(cluster_sometimes) > len(cluster_always) and len(cluster_never) > len(cluster_always))):
        Falls under moderate risk
```

### 4.2 Extracting

In this phase, the child is provided with a set of 25 questions varied across five categories-

1. Numeric (recognize the numbers, match the numbers with corresponding words)
2. Sequence (write in ascending and descending order, tell which number comes before and after a particular number)
3. Counting (count the objects and write the correct number)
4. Comparing (compare the numbers and write whether it is greater than, lesser than, or equal to)

5. Arithmetic operation (perform the operations of addition and subtraction)

The child has to answer these questions based on its understanding. The software generates a bitmap pattern depending upon whether the child passes each section with minimum criteria of 80%. For eg if the child is unable to score satisfactory in numeric, counting, and comparing, the pattern generated will be 01001. The software is capable of generating a total of $2^5 = 32$ patterns depending upon the performance of the child. The generated pattern is used to identify the areas in which the child lags.

The objective of the computer-based test is to design it in an interactive manner that captures the child's attention and increases its concentration span. Various audio files and images are included to meet the above-stated objective.

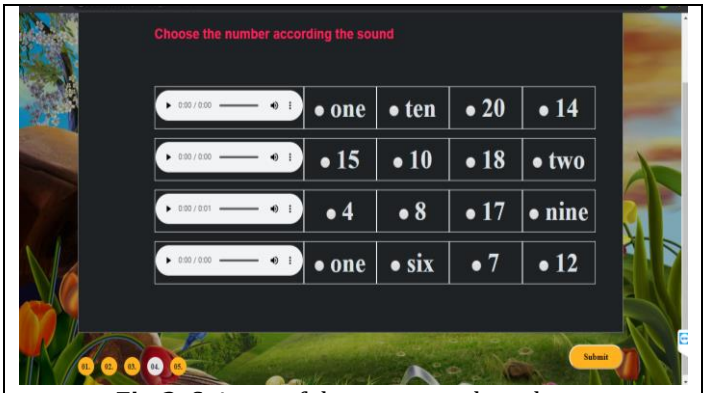


**Fig-2:** Snippet of the computer-based test


**Fig-3:** Snippet of the computer-based test

## 4.3 Remedy

In this phase, various types of games are designed to teach the child the basic concepts of mathematics. For the defined five categories, the child is provided with a remedy in the form of games.

**Table 3 –** Mathematical games designed for dyscalculic children

| Sr. No. | Remedy for Type | Title | Description |
|---|---|---|---|
| 1. | Numeric | Let's Play A Tune For The City. | Every tile is associated with the corresponding sound of the number. |
| 2. | Numeric | Discover The Mysterious Tiles. | Matching the same tiles will help to build the memory |
| 3. | Numeric | Save The Planet From The Asteroids. | Learn the sound of the number which is displayed on the asteroid |
| 4. | Numeric | Let Us Discover The Mysterious Correlation. | Relate the spelling of the number with its corresponding digit with the help of sound |
| 5. | Sequence | Help The Bunny Jump The Numbers. | Learn the sequence of the numbers with the help of sound. |
| 6. | Sequence | Save The City From The Falling Blocks. | After clicking on the falling blocks, sound can be heard in a sequential manner |
| 7. | Sequence | Help The Snake Munch Those Numbers. | Make the child learn the sequence by controlling the snake with the help of arrow keys. |
| 8. | Counting | Oh So Many Images. | Count the number of images displayed on the screen and hit the corresponding number |
| 9. | Counting | How Many Apples? | Count the images displayed on the screen and write the corresponding number in the box |
| 10. | Compare | Smash The Numbers. | Smash the number to find out whether it is smaller or greater than the displayed number |

| | | | |
|---|---|---|---|
| 11. | Compare | Let Us Spread Happiness. | Help the child in memorizing the relation between the numbers. |
| 12. | Arithmetic Operation | Count and Add Numbers. | Count the objects displayed on the screen and add them to understand the meaning of the sign '+'. |
| 13. | Arithmetic Operation | Add Before The Time Runs Out. | Adding the timer will help the brain to add the numbers quickly. |
| 14. | Arithmetic Operation | Count and Subtract the Number. | Count the objects displayed on the screen and subtract them to understand the meaning of sign the '-'. |
| 15. | Arithmetic Operation | Subtract Before The Time Runs Out. | Adding the timer will help the brain to subtract the numbers quickly. |

The games designed, are divided into five modules- number, sequence, counting, comparison, and calculation. Until and unless the child shows proficiency in the first module, it cannot move on to the next module. Each game has a set high score and if the child manages to score equal to or greater than the high score it is provided with a set of 10 questions to check the concepts it has learned while playing the games. If the child manages to score criteria of 80% in the test, it moves on to the next module. Otherwise, it will have to continue to play the games of the same module.

## 5. RESULTS AND DISCUSSION

In this software, we implement gamification elements such as comparative analysis (in the form of a graph), points, dashboards, and awards. Also, the software sends a progress report to the parent's/teacher's email id that indicates the learning curve of their ward.

### 5.1 Comparative Analysis (Graphical Format)

The graphical analysis is generated with the help of linear regression. The two curves plotted on the screen are:

1. The graph in red shows the performance of the child in the test given by it during pattern evaluation.
2. The graph in green indicates the performance of other children using the same software and has given the pattern evaluation test. This graph is dynamically plotted as new data keeps on loading, as and when a new child registers in the software.

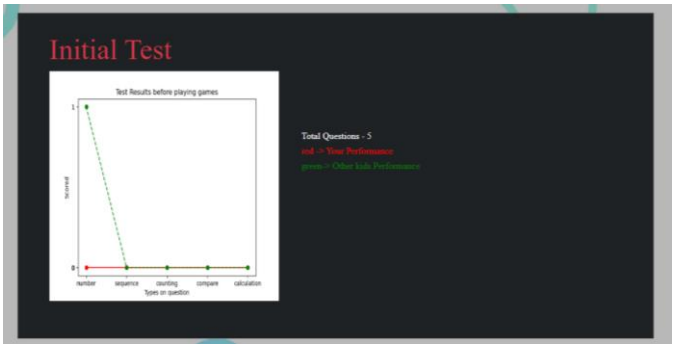


**Fig-4:** Comparative analysis

#### 5.1.1 Formula Used

The equation of regression line is represented as:
y = b0 + b1 * x
b1 = sum((xi-mean(x)) * (yi-mean(y))) / sum((xi – mean(x))^2)
We calculate b0 from b1 and statistics from our data:
b0 = mean(y) – b1 * mean(x)

### 5.2 Points

This element is included to boost the child's confidence as well as motivate it to improve its performance, by awarding points for its efforts. In order to ensure the child feels motivated in the learning environment, each time the child plays a game it is awarded 10 points. And if it manages to score equal to or greater than the set high score it is awarded 20 points.

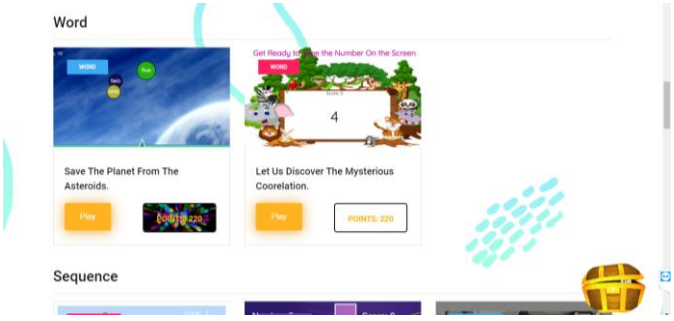


**Fig-5:** Points scored by the child

### 5.3 Dashboard

As and when the child manages to score equal to greater than the set high score, it is presented with a computer-based test having 10 questions based on the concepts it has learned in a particular game. The performance marker is in the form of a graph since graphs are easy to understand and

interpret. The performance of the child for each module in the computer-based test is plotted on the screen.

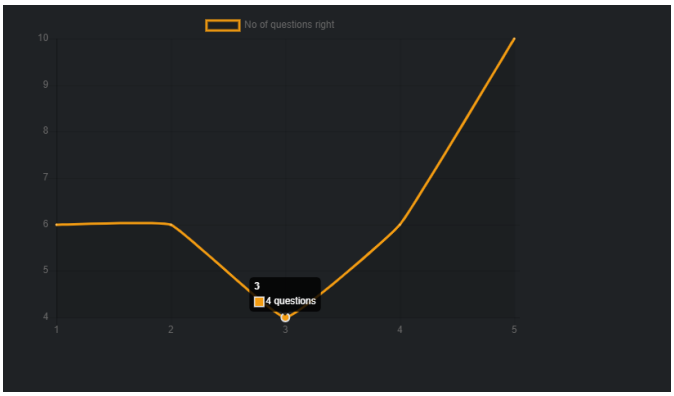


**Fig-6:** Graph indicating the progress of a child

## 5.4 Awards

Awards presented to the child give it a sense of accomplishment which is necessary to boost the confidence and keep it motivated to continue learning. So, when a child scores above 80% in the post-learning evaluation test, it is awarded a star.


**Fig-8:** Awards received by the child

## 5.5 Progress Report

Once the system analyzes that the child is showing progress in the area in which it initially lagged, a report is sent to the parent's/teacher's email id. This progress report consists of two graphs- the first, indicating its performance before the learning module, and the second, indicating its performance after going through the learning module of the software.

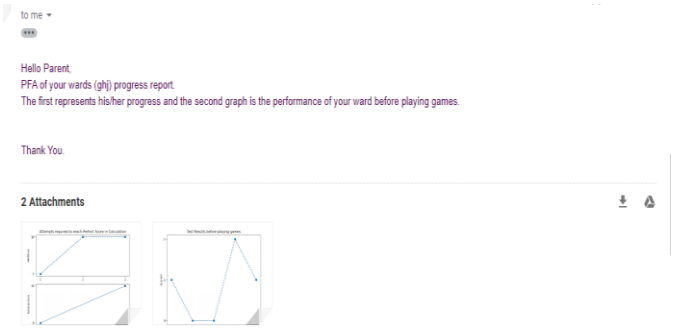


**Fig-9:** Progress report of a child sent to a parent

## 6. CONCLUSION

Dyscalculia is a learning disability which although cannot be entirely eliminated but the condition can be improved with the help of various technological aids. Gamification as a technological aid is more effective than game-based learning and traditional methods of learning. Math Warrior focuses on the age group of 3 to 5 years. This software not only identifies the signs of dyscalculia and areas in which the child lags but also provides a remedy by implementing gamification. The tests conducted at various stages of the software helps to keep a track of the progress made by the child and generate a progress report that will help the parent/teacher to track their child's learning curve. Gamification not only helps in boosting the child's confidence but also improves its mathematical skills, which sets it on a path of personal growth.

## ACKNOWLEDGEMENT

We would like to thank the Maharashtra Dyslexic Association for their help in giving us a brief idea about dyscalculic children. We would also like to thank our guide Ms. Nisha Vanjari for her guidance. We would like to express our gratitude towards all the authors and researchers for their work in helping dyscalculic children by conducting various studies and developing software that motivated us to do the same.

## REFERENCES

[1] Mhd. Rizky Ferianda, Anisa Herdiani, Indra Lukmana Sardi, "Increasing students interaction in distance education using gamification", 2018 6th International Conference on Information and Communication Technology (ICoICT).

[2] Pinedo Rivera Dafne Ifigenia, Muñoz Arteaga Jaime, Broisin Julien, Ponce Gallegos Julio Cesar, "Integration of gamification to assist literacy in children with special educational needs", 2018 IEEE Global Engineering Education Conference (EDUCON).

[3] Kevin S. McGrew, Erica M. LaForte, Fredrick A. Schrank, "Woodcock Johnson IV", Technical Manual.

[4] [online] Available at: https://dopasolution.com/dyscalculia

[5] [online] Available at: https://www.understood.org

[6] Kadosh, R. C., Kadosh, K. C., & Henik, A., "When brightness counts: The neuronal correlate of numerical-luminance interference", Cerebral Cortex, 18(2), 337–343.

[7] Cohen Kadosh, R., Cohen Kadosh, K., Schuhmann, T., Kaas, A., Goebel, R., Henik, A., & Sack, A. T., "Virtual dyscalculia induced by parietal-lobe TMS impairs automatic magnitude processing", 2007, Current Biology, 17(8), 689–693.

[8] Antonia, P., Catherine, B., & Panayiotis, V., "Cognitive science: From molecular biology to brain function", 2015 6th International Conference on Information, Intelligence, Systems and Applications (IISA).

[9] Filipa Ferraz, José Neves, "A brief look into dyscalculia and supportive tools", 2015 IEEE International Conference on E-Health and Bioengineering.

[10] Tahan, O., & Barake, F., "A gaming environment to train teachers diagnose children learning disabilities."2018 14th International Computer Engineering Conference (ICENCO).

[11] Aljowaysir, N., Ozdemir, T. O., & Kim, T., "Differentiated learning patterns with mixed reality", 2019 IEEE Games, Entertainment, Media Conference (GEM).

[12] Erick Lozano Borges, Pedro Henrique Cacique Braga, Ilana de Almeida Souza Concilio, "Application to help the learning process of children with dyscalculia", 2018 XIII Latin American Conference On Learning technologies.

[13] Andrea Biancardi, Rita Francese, Michele Risi, Mario Procida, "DyscalcTest generation environment: supporting the clinician in the creation, delivery and evaluation of dyscalculia tests", 2019 23rd International Conference Information Visualisation (IV).

[14] Élise Lavoué, "LudiMoodle: Adaptive gamification to improve learner motivation", 2019 Université Jean Moulin Lyon.

[15] L. S. Beatty, "Stanford Diagnostic Mathematics Test: Brown Level : Manual for Administering and Interpreting", Harcourt Brace Jovanovich, 1976.

[16] H. Ginsburg and S. C. Mathews, "Diagnostic Test of Arithmetic Strategies", Pro-Ed, 1984.

[17] V. L. Brown and E. McEntire, Test of Mathematical Abilities, Pro-Ed, 1990.

[18] S. E. Colson, A Curricular Validation Study of the Hudson Education Skills Inventory Test of Mathematics, University of Kansas, Special Education, 1987.

[19] H. P. Ginsburg and A. J. Baroody, Test of Early Mathematics Ability, Pro-Ed, 1990.

[20] B. Butterworth, Dyscalculia Screener, London: nferNelson, 2003.

[21] Vanjari, Nisha and Bakre, Snehal and Parmar, Ronak and Singal, Vidhisha, Technological Aids for Dyscalculic Children (April 8, 2020). Proceedings of the 3rd International Conference on Advances in Science & Technology (ICAST) 2020