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Early Detection of Dyslexia, Dyscalculia, Dyspraxia, Dysgraphia using Machine Learning

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ABSTRACT:

Identifying and diagnosing learning disabilities like dyslexia, dysgraphia, dyscalculia, and dyspraxia pose significant challenges in educational and clinical contexts. Machine learning offers a promising avenue for aiding in early detection and intervention for these conditions. In this study, we propose a comprehensive approach utilizing machine learning algorithms tailored to each specific learning disability. To detect dyslexia, we analyze eye fixation data from eye- tracking devices during reading tasks, employing classification algorithms to discern characteristic gaze patterns indicative of dyslexic traits. For dysgraphia identification, convolutional neural networks (CNNs) analyze handwriting samples, extracting features that signal dysgraphia and enable precise classification. Furthermore, for dyscalculia and dyspraxia detection, linear regression models analyze cognitive and motor skill assessments, predicting the presence and severity of these conditions based on performance metrics. By integrating diverse machine learning methodologies, our study seeks to improve the accuracy and effectiveness of learning disability detection, thereby facilitating timely intervention and support for affected individuals in educational and clinical settings.

Keywords: SLD(Specific learning disorder), Dyslexia, Dysgraphia, Dyscalculia, Dyspraxia, Machine Learning (ML), Handwriting Analysis, Eye-tracking

INTRODUCTION

Specific learning disability commonly known as SLDs is an abbreviation used to generalize disorders concerning the learning and behavioral capabilities of an individual, which collectively includes Dyslexia, Dysgraphia Dyspraxia, and Dyscalculia. These are neurological disorders that can be detected but not prevented, however can be treated. Multiple studies have identified different brain structures involved in abnormal neural development associated with dyslexia[1].

Specific learning disorders are usually mistaken for just dyslexia, whereas these are further classified majorly into four types dyslexia, dyspraxia, dysgraphia, and dyscalculia.4% to 10% of the general population are prone to Dyslexia. Although it hugely perturbs the smooth working of our neural system it also adversely affects the brain impairing a person's reading abilities.[1,2] Dyslexia is a reading disability, and correlating speech sounds to those specific words, in other words, basic processing of language. [1,3] Dyspraxia is the impairment of basic organizational and execution of physical movements and affects 2- 5% of the world's population[4],this is caused due to perceptual problems, including visual-motor and difficulties which further result in motor problems and speech difficulties.[3,5] This is usually detected by careful observation of the individual and close physical inspection by physiotherapists in selected cases.[5]

The writing disability in SLD is called Dysgraphia, this refers to the inability to write coherently in individuals that disables them from coordinating their writing skills despite the provided exposure, (eg common confusion between p and q, and b and d)[2].
Lastly, Dyscalculia is the inability to understand arithmetic information, this includes numbers and basic operations. There could be a potential overlap between Dysgraphia and dyscalculia since both disorders involve confusion between similar-looking terms.
The current solutions to these SLDs involve variations from games to quizzes that cover a variety of SLDs, based on the research done, there are machine learning models that determine the presence of SLDs in individuals most of which cover dyslexia, dysgraphia, and dyscalculia, major

chunk of these software miss to address the issues and treat Dyspraxia. These commonly make use of ML algorithms like Random Forest division, KNN, CNN and Adaptive Boosting.

Detection of specific learning disabilities traditionally relied on a multifaceted approach encompassing careful observation by educators, parents, and healthcare professionals to note symptoms like reading or writing difficulties, coordination issues, or struggles with mathematical tasks. Physical examinations conducted by physiotherapists and healthcare providers were pivotal, especially for identifying dyspraxia, which manifests as challenges in physical movements.

Handwriting analysis played a crucial role in identifying dysgraphia, examining patterns such as illegible handwriting and confusion between similar letters. Educational assessments conducted within school environments helped evaluate students' academic abilities, with teachers monitoring progress and identifying any discrepancies or challenges in reading, writing, or mathematical skills.

An Indian study found that the prevalence of impairment in reading and written expression was 22% each and impairment in mathematics was 16%. In primary school children in India, the prevalence of dyslexia, dysgraphia, and dyscalculia has been reported to be 11.2%, 12.5%, and 10.5%, respectively. SLD or specific learning disabilities is the umbrella term Worldwide, around 10% of the population has dyslexia, a specific learning disorder.[6] early detection of the risk of dyslexia is very extensive and comes from different fields such as cognitive neuroscience, psychology, or biology.[6]

LITERATURE SURVEY

Detection of Dyslexia, Dysgraphia, Dyscalculia and Dyspraxia, each of which presents unique challenges in academics and everyday life. Dyslexia, characterized by difficulties in reading and understanding words, affects a significant proportion of the population, mainly school-going males. Early detection is critical to prevent symptoms from worsening and reduce the impact on self-esteem and academic performance. Eye-tracking technologies combined with machine learning algorithms such as k-nearest neighbors (KNN),show promise for detecting dyslexia with 72.7-83.61% accuracy.

Similarly, dysgraphia focuses on writing. difficulties, affect a significant percentage of children, especially boys. Handwriting analysis supported by machine learning techniques such as Convolutional Neural Networks(CNN)helps detect dysgraphia, albeit with variable accuracy of 65-83.61%. Ongoing assessment and intervention, including occupational or physical therapy, are necessary to manage dysgraphia symptoms and improve learning outcomes.

The progression to dyscalculia, the inability to understand numerical information, challenges math comprehension and calculation. Although research in this area has led to classifications such as primary and secondary dyscalculia, the development of detection software is still limited. Similarly, dyspraxia, which affects the functioning of motor skills, creates obstacles in daily tasks and cognitive functioning. Machine learning algorithm including Random Forest help detect dyspraxia. The modified Random Forest has the highest accuracy of 78.02%.

Finally, understanding and treating learning disabilities through early detection and appropriate interventions is essential to improve academic performance and quality of life for those affected. Machine learning techniques provide valuable tools to accurately identify and design interventions for various learning disabilities, paving the way for improved support and outcomes in educational and clinical settings.

METHODOLOGY

DYSLEXIA

Eye fixation techniques are instrumental in identifying dyslexia, a condition characterised by challenges in reading and language comprehension. These methods encompass a variety of approaches, including the utilisation of eye tracking technology, its integration into standardised reading assessments, and the implementation of tasks like visual search and non- word reading. Through the careful analysis of eye movement patterns during these tasks, researchers and clinicians can pinpoint specific patterns associated with dyslexia, enabling early detection and the development of customised intervention strategies tailored to individual needs.

Moreover, insights into the visual processing difficulties encountered by individuals with dyslexia are provided through fixation duration analysis, letter recognition tasks, and visual attention tests. By gaining a comprehensive understanding of these fixation patterns and visual processing inefficiencies, professionals can design interventions aimed at improving reading skills and language comprehension. Ultimately, these interventions have the potential to enhance academic and social outcomes for individuals with dyslexia, empowering them to thrive in various aspects of life.

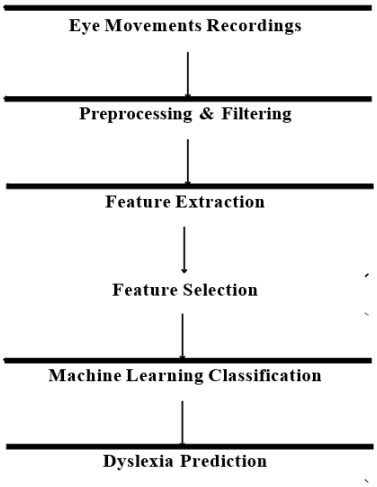

fig: Blackbox Representation of Dyslexia

DYSGRAPHIA

Incorporating Convolutional Neural Networks (CNN) to detect dysgraphia through handwriting analysis provides a state-of-the-art solution to improve accessibility and support users with learning disabilities. Using CNN , handwriting samples can be analysed with unprecedented accuracy and efficiency, allowing the identification of patterns indicative of dysgraphia. CNN extracts hierarchical features from handwritten images, allowing the platform to classify users based on delicate differences of their writing style. This approach allows dynamic adjustment of interface elements such as font size, spacing, and layout to better accommodate users with dysgraphia and improve their overall user experience .Users can actively promote digital inclusion and ensure equal access to online resources for people with dysgraphia.

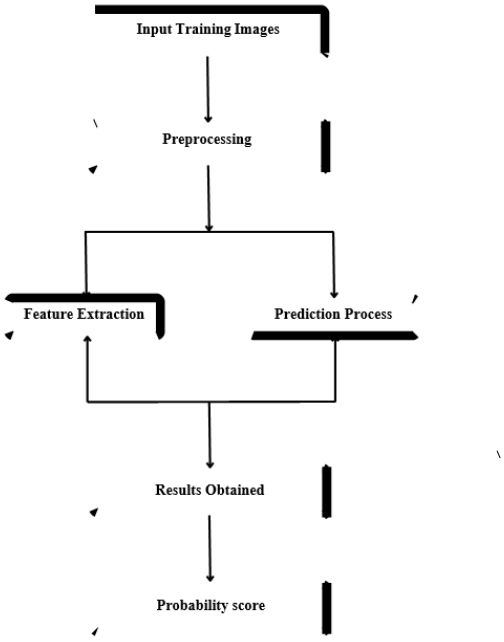

fig: Blackbox Representation of Dysgraphia

DYSCALCULIA

Utilizing linear regression for dyscalculia detection involves employing mathematical models to analyze data patterns and relationships, aiming to predict the presence of dyscalculia. Linear regression, a statistical method, seeks to establish a linear connection between independent variables (such as numerical abilities, mathematical performance, etc.) and a dependent variable (the presence or severity of dyscalculia). By fitting a linear equation to the data, the model predicts the likelihood of dyscalculia based on observed characteristics. This approach requires a dataset comprising relevant features and labels, including standardized test scores, diagnostic assessments, and demographic information, to train and validate the regression model. Additionally, selecting appropriate features and employing preprocessing techniques are essential to ensure the accuracy and reliability of the predictive model.

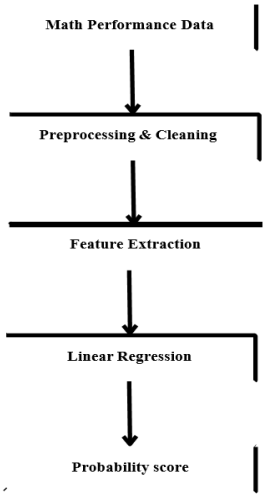

fig: Blackbox Representation of Dyspraxia and Dyscalculia

DYSPRAXIA

Detecting dyspraxia using linear regression involves employing mathematical models to analyze data patterns and relationships, with the goal of predicting the presence of dyspraxia. Linear regression, a statistical method, aims to establish a linear relationship between independent variables (such as motor skills, coordination abilities, etc.) and a dependent variable (the presence or severity of dyspraxia). By fitting a linear equation to the data, the model estimates the likelihood of dyspraxia based on observed characteristics. This approach relies on a dataset containing relevant features and labels, such as standardized assessments, diagnostic evaluations, and demographic information, to train and validate the regression model. Additionally, the careful selection of features and the application of preprocessing techniques are essential to ensure the accuracy and reliability of the predictive model.

CONCLUSION

In summary, this study navigates the complex understanding of Specific Learning Disabilities (SLDs), encompassing Dyslexia, Dysgraphia, Dyspraxia, and Dyscalculia. It elaborates the interrelation between these neurological disorders and their coexistence in various permutations, often accompanied by ADHD. The research explains the current landscape of detection methodologies, ranging from neuroimaging techniques like fMRI, PET, and MEG to innovative machine learning-based solutions. Eye-tracking algorithms aid Dyslexia identification, while handwriting analysis, supported by machine learning models such as Random Forest, KNN, CNN and Adaptive Boosting, contributes to Dysgraphia detection. This exploration highlights the need for holistic detection methods encompassing these disorders, acknowledging the gaps in addressing Dyspraxia and underscoring the importance of personalized interventions. Bridging neurological, machine learning, And behavioral approaches is crucial for comprehensive SLD detection and tailored interventions.

FUTURE ENHANCEMENT

In order to enhance the project focused on Specific Learning Disabilities (SLDs), future improvements can encompass a more inclusive coverage, expanding beyond dyslexia, dysgraphia, dyspraxia, and dyscalculia. Develop adaptive learning paths utilizing artificial intelligence (AI) algorithms to tailor interventions to individual needs, providing a personalized and effective learning experience. Enhance user engagement

with interactive and gamified content, incorporating multimodal learning approaches to accommodate diverse learning styles. Implement early detection tools and interventions, collaborating with healthcare professionals for a holistic approach.

Integrate speech recognition technology to assist individuals with dyslexia in improving reading and pronunciation skills. Ensure mobile accessibility for flexibility, and establish a system for long-term progress tracking to evaluate intervention effectiveness. Foster a supportive community platform for individuals, families, and educators to share experiences and resources. Regular user testing and feedback collection are crucial to align enhancements with the needs of the target audience and contribute to the overall success of the project.

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