# DETAILED REVIEW OF VARIOUS METHODS FOR DYSLEXIA DETECTION ANALYSIS

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**ABSTRACT**: Dyslexics can largely learn to read, write and study effectively when they use methods designed to their unique learning style. Based on recent progress in theory and dyslexia measurement techniques, the analysis of eye movements has become one of the major methodological tools in experimental reading research. For this reason, the research on dyslexia detection is getting popular, which is based on the image processing concepts. In this review work we attempt to discuss about image processing techniques, feature extraction and feature selection, various classification techniques used in image processing. The chapter also deals with learning disability and its types, measures of eye movements and how they are related to dyslexia. The major issues and advantages of each method are discussed clearly in this review work. At finally review work discussed about the scope of the future and research gap.

**INDEX TERMS**: Dyslexics, Dyslexia Detection, Data mining, learning disability, image processing techniques, feature extraction, and feature selection.

## 1. INTRODUCTION

Data mining applications in health care have been proved as tremendous potential usefulness in diagnosing diseases. Today in the medical domain, advanced technologies like automated systems, diagnosing or predicting systems, healthcare systems are available for early detection and prevention of diseases. These systems require exploration and manipulation efficiency in handling large databases in developing any decision support system. The more focus on data mining techniques in extracting useful or meaningful patterns from the existing data helps any medical diagnostic system.

Using analytics in the educational context to understand the individual's behaviour is an upcoming researching concept in the modern data mining area. Becoming a new relative area of practice and research, different types of approaches and wide varieties of terms have been introduced. Dyslexia is characterized by dysfunction of the normal left hemisphere language network and also implicates abnormal white matter development. Generally dyslexic persons use five times the brain areas as normal persons while performing a simple language task. Dyslexic person brain consists of slightly misplaced cells called ectopias and some minor disordering of the regular layering of cells in the cortex. The persons affected by dyslexia also have 'visual symptoms' when they try to read the letters and words it appears to move or blur on the page.

All slow learners are not dyslexic. Dyslexic persons usually be lazy, their left brain activities will be slow. Dyslexia is the result of neurological difference; it is not an intellectual disability. Due to implicit characteristics of dyslexia, identification of individuals suffering from this problem has long been a difficult issue. Researchers believe that the use of learning analytics in higher education will grow further with such importance of identifying the student behaviour in the educational domain. Currently any types of institution, from a college to a university, academic analytics are being used to increase the financial and operational efficiency of the students. In order to cope with the high demands in the students learning (Cain ,2010) indicated that many of the critical questions in business are appearing parallel to higher education as well (Bienkowski et al. 2012). To address these issues in higher education many researches are currently implementing practices, focused on student retention, admission and operational efficiency.

According to the study conducted by the U.S. Department of Education, the most common reasons for students' dropping out of school are based on the following reasons

- Lack of educational support - many students decided to drop out of high school due to lack of sufficient parental support and educational encouragement.
- Special needs - students often drop out of high school because they require specific attention to a certain need, such as dyslexia or other learning disabilities.
- Financial problems.

Out of the three mentioned above, the lack of educational support and the financial problems can be easily managed. But the identification of those students with special needs like dyslexia students is very difficult in data mining. For this reason, the research on dyslexia detection is getting popular, which is based on the image processing concepts. In this review work we attempt to discuss about image processing techniques, feature extraction and feature selection, various classification techniques used in image processing. The chapter also deals with learning disability and its types, measures of eye movements and how they are related to dyslexia.

## 2. REVIEW WORK

The analysis of associated literature is necessary and it plays a major role in research work. Study constantly takes the benefit of the knowledge, which has gathered in the precedent as a result of human endeavour. For any valuable

research, the research worker requirements adequate knowledge with the literature obtainable in with the purpose of ground of study. The keys to the vast store house of published literature might open doors in the direction of source of significant problems, good hypotheses, helpful orientation, scientific procedure and comparative data for interpretation of results. The documents comprise periodicals, abstracts, reviews, books and other research reports.

Researchers, neurologists, investigators, parents and teachers have developed various architecture models, simulated systems, prototypes for reasonably accurate prediction/detection of dyslexia. This chapter is an attempt to review conventional dyslexia detection methods, eye movement based dyslexia detection, feature extraction, feature selection methods, artificial neural network, adaptive neuro fuzzy inference system, particle swam optimization technique, support vector machine and fuzzy membership function with adaptive neuro fuzzy inference system. Relevant literature related to these works are condensed and given below.

### 2.1. REVIEW ON CONVENTIONAL DYSLEXIA DETECTION METHODS

Aylwardet al. (2008) explained different neuro imaging technologies for revealing the biological basis of reading and dyslexia. fMRI is most suited to localisation of function, and hence to investigating the neural networks that underpin efficient (or inefficient) reading. Electro EncephaloGraphy (EEG) is sensitive to millisecond differences in timing, hence it is suited for studying the time course of processing Neuro imaging studies of developmental dyslexia are then reviewed, focusing on (a) the neural networks recruited for reading, (b) the time course of neural activation and (c) the neural effects of remediation. Representative studies using the different methodologies are selected. This study shows that dyslexic brain is characterised by under-activation of the key neural networks for reading.

Karstenspechtet al. (2008) studied fMRI, for adults, considered at risk for dyslexia were compared with an age-/gender-matched control group for differences in brain activation when presented with visual stimuli differing in demands for literacy processing. Stimuli were nameable pictures, brand logos familiar to individuals, and written words – these were either regularly spelled using early-acquired rules (“alphabetic”) or more complex (“orthographic”). Brain responses distinguished between the presentation conditions, as a function of group, within many cortical areas.

Soo Yeon Ji & KayvanNajarian (2008) designed a hierarchical method that applies an optimization algorithm based on Modified Maximum Correlation Model (MMCM) that can detect small variations across the two study groups. Based on the this method, they also hypothesize that dyslexia might represent functional Magnetic Resonance Imaging (fMRI) brain signal activities in specific regions of the brain that are distinguishable from healthy brain fMRIs. The limitation of this study was the small size of the dataset used to identify the fMRI brain activity. Even though the dataset was small sized, the method successfully process the active raw time series in both dyslexic and healthy subjects in order to distinguish regions differentially activated in the two groups.

Schulz et al. (2008) recorded brain activity of 47 persons (16 with dyslexia, 31 controls) with fMRI and Event-Related Potentials (ERP) in two separate counter balanced sessions. The person silently read and occasionally judged simple sentences with semantically congruous or incongruous endings. fMRI and ERP activation during sentence reading and semantic processing was analyzed across all the individuals and also by comparing an individual with dyslexic and healthy subjects. For sentence reading, the analysis is made based on response to all words in a sentence. Sentence reading was characterized by activation in a left-lateralized language network. Semantic processing was characterized by activation in left-hemispheric regions of the inferior frontal and superior temporal cortex and by an electrophysiological N400 effect after 240 ms with consistent left anterior source localization. A person with dyslexia showed decreased activation for sentence reading in inferior parietal and frontal regions, and for semantic processing in inferior parietal regions. Together, this suggests that semantic impairment during sentence reading reduces dyslexic person’s response in left anterior brain regions.

Soo-YeonJiet al. (2009) evaluated the capability of a hierarchical method that performed an optimization algorithm based on MMCM. The optimization algorithm was designed by adopting modified maximum correlation model to detect active regions that contain significant responses. The optimization algorithm was examined based on two groups of datasets, dyslexia and healthy subjects, to verify the ability of the algorithm that enhances the quality of signal activities in the interested regions of the brain. After verifying the algorithm, Discrete Wavelet Transformation (DWT) is applied to identify the difference between healthy and dyslexia subjects. In this research work, they have concluded that the wavelet transform is an appropriate non-stationary signal analysis method, which may be suitable for differentiating two different conditions.

Peyrinet al. (2012) explained Visual Attention (VA) span disorders have been reported in dyslexic persons. This study investigates whether this cognitively-based dissociation has a neurobiological counterpart through the investigation of two cases of developmental dyslexia. Learning level showed a phonological disorder but preserved VA span whereas Frontal Gyrus (FG) exhibited the reverse pattern. During a phonological rhyme judgement task, LL showed decreased activation of the left inferior Frontal Gyrus whereas this region was activated at the level of the controls in FG. Conversely, during a visual categorization task, FG demonstrated decreased activation of the parietal lobules whereas these regions were activated in LL as in the controls. These contrasted patterns of brain activation thus mirror the cognitive disorders’ dissociation.

### 2.2. REVIEW ON FEATURE EXTRACTION METHODS

Hutzler&Wimmer (2004) Participants were German dyslexic readers who—compared to English dyslexic readers—suffer mainly from slow laborious reading and less from reading errors. The eye movements of eleven dyslexic boys and age-matched controls were recorded during reading of text passages and pseudoword lists. Comparisons across studies suggest that the present German dyslexic eye movement findings differ from English-based findings by a lower frequency of regressions (presumably due to the higher regularity of German) and from Italian findings by longer fixation duration (presumably due to the greater syllabic complexity of German).

Stefan Hawelkaet al. (2005) presented eye-movements, which represent a great interest in studying the specificity of the reading difficulties that individuals with developmental dyslexia have. The children read sentences in Bulgarian – a Cyrillic alphabet language with regular orthography. Target nouns with controlled frequency and length were embedded in the sentences. Eye movements revealed highly significant group differences in the gaze time and the total fixation times, word frequency and word length effects as well as interaction for both frequency and length with the group factor.

The non-reading task used by Hutzleret al. (2006) was considered to be still closer to the perceptual and oculomotor demands of reading. In this study, the dyslexic and control participants had to read aloud series of pseudo-words (e.g., GUFT). The consonant strings were built from the pseudo-words by replacing vowels by consonants. The spatial arrangement of pseudo-words and consonant strings was the same. The eye movement patterns of dyslexic and control readers did not differ when performing the visual search task, whereas they strongly differed in the reading task. Such findings were interpreted as evidence against the hypothesis of visual perceptual or oculomotor problems in developmental dyslexia.

Chloe Pradoaet al. (2007) explained eye movements of 14 French dyslexic persons having a VA span reduction and 14 normal readers were compared in two tasks of visual search and text reading. The dyslexic participants made a higher number of rightward fixations in reading only. They simultaneously processed the same low number of letters in both tasks whereas normal readers processed far more letters in reading. Importantly, the person's VA span abilities related to the number of letters simultaneously processed in reading. The typical eye movements of some dyslexic readers in reading thus appear to reflect difficulties to increase their VA span according to the task request.

Kerstin et al. (2010) used eye movements approach to advance the understanding of impaired information processing in acquired central dyslexia of stroke patients with aphasia. Till now there has been no research attempting to analyze both word based viewing time measures and local fixation patterns in dyslexic readers. The goal of the study was to find out whether specific eye movement parameters reflect pathologically preferred segmental reading in contrast to lexical reading. They compared oral reading of single words of normal controls (n = 11) with six aphasic participants. Their mean fixation duration was already prolonged during first pass reading reflecting their attempts of immediate access to lexical information. After first pass reading, re-reading time was significantly increased in all participants with acquired central dyslexia due to their exceedingly higher monitoring demands for oral reading.

Servet Bayramet al. (2012) examined and compared dyslexic and normal readers, reading habits and eye movements during reading passages and pseudowords. Participants were 15 Turkish dyslexic students, suffering mainly from reading disorder. In addition there were 15 Turkish students who were regular readers and who did not have problems with reading. During reading passages and pseudowords, the eye movements of participants were recorded. For both text and pseudoword reading, the dyslexic readers exhibited more and much longer fixations, but relatively few regressions. An increased length of words and pseudowords led to a greater increase in the number of fixations for dyslexics rather than normal readers.

### 2.3. REVIEW ON FEATURE SELECTION METHODS

Macaset al. (2013) described an application of Hidden Markov Models (HMM) to dyslexia detection from eye movements. Eye movements of reading dyslexic and control groups are measured, pre-processed and Hidden Markov Model with two hidden states are trained on velocity time series for each person. The two states of the model correspond to two component of the eye movements signal - fixations and saccades. The elements of transition matrix are further used one by one as features for 1-dimensional linear Bayes classifier. It is shown that this method applied to eye movements during the simplest non-verbal task can lead to relatively high performance. Thus, this work proposed the feature extraction.

Karimet al. (2013) studied the EEG based identification of dyslexia for individuals. Dyslexia is a learning difficulty and in most cases cannot be identified until a person is already in the third grade or later. At this time a dyslexic person have only one-in-seven chance of ever catching up with his or her peers in reading, writing, speaking or listening. Early identification can pave the way for early intervention and the dyslexic person can be helped at an early stage. Furthermore, the results yielded are the best when the intervention is in the form of providing specialized instructions or carried out through some other way yields best results. In this analysis, feature extraction is carried out using KDE and MLP is used for classification of the features extracted. The results show promising classification accuracy.

Dong ping &Tian (2013) presented that feature extraction and representation is a crucial step for multimedia processing. According to their survey, the conclusion was to explore the relationship between features' number and the final performance. Intuitively, it is not possible that the more the features' number, the better the final performance. Second, to explore the relationship

between features' representation and the final performance is also a very interesting and challenging topic. It involves the feature representation methods (global, block-based and region-based features). Specifically, in the case of block-based and region-based features, the final performance partially depends on the size of the partition or segmentation. Third, it is also interesting to explore the relationship between their appropriate combination and the final performance to see whether the combination can further improve the performance.

### 2.4. REVIEW ON CLASSIFICATION BASED DYSLEXIA DETECTION METHODS

Novak et al. (2004) presented a Self Organizing Map (SOM) and Genetic Algorithm (GA) for extraction of set of features for detection of eye movement signal in both horizontal and vertical manner. They concluded that the reading speed enlarged with the likelihood of the patient being healthy. In this method, an inductive modeling technique was applied to data set resulting in extraction of six features which were used as the input to Self Organizing Map (SOM). Three clusters were finally formed by the SOM proving that the proposed methodology is suitable for automatic dyslexia analysis. Lei yuet al. (2004) applied feature selection for many applications where data has hundreds and thousands of features. The authors proposed a new framework of efficient feature selection through relevance and redundancy analysis. This work has been implemented in supervised learning where data contains many irrelevant and/or redundant features. Wu et al. (2008) proposed feature selection for learning disability diagnosis problem. In this work, a GA-based feature selection algorithm is proposed as the pre-processing step. And this wrapper-based GA feature selection procedure can improve the learning disability identification accuracy.

### 2.5. REVIEW ON EYE MOVEMENT BASED DYSLEXIA DETECTION METHODS

Eye tracking has received considerable attention as a new source of data for research into the information search process. Much of the work in information science using eye tracking data has concentrated on eye fixations Pan et al. (2007); Brumby &Howes (2008).

Macaset al. (2005) developed a scheme for extracting the features of eye movements from time and frequency domain. They accomplished that Back Propagation (BP) based classification have higher accuracy for detection than the result of Bayes network. The main goal was to analyze the possibility of dyslexia detection only from the eye movement signal. Time and frequency domain features were extracted and subset of significant features was chosen by a simple feature selection method. The selected feature subset was visualized using a SOM. Clusters were formed by the SOM proving that proposed methodology is suitable for automatic dyslexia detection.

Wu et al. (2006) introduced a MLP with back propagation which shows that improved results in diagnosing LD. The procedures are based on empirical findings from scholarly research. In their work, the authors try to adopt Artificial Neural Network (ANN) technique, which has been applied successfully to solve problems in numerous fields, to the LD identification and diagnosis problem. It is guaranteed for every potential LD students to adopt two well-known artificial intelligence techniques (Artificial Neural Network and Support Vector Machine), which have been applied successfully to solve problems in numerous fields, to the LD identification and diagnosis problem. The advantage is elimination of possible human bias.

MacLean (2007) is an extension of SOM clustering algorithm that utilize the general behaviour and parallel capabilities of the normal SOM by calculating the success result for each signal in parallel. A regressive eye movement was slightly improved to show the result for dyslexic rather than for well organized readers and usual readers. Differences were not simply in total number of regressions, but moreover is the percentage of total amount of eye movements of regressions.

Wu et al. (2008) proposed Artificial Intelligence Techniques, Artificial Neural Network (ANN) and Support Vector Machine (SVM), to the LD diagnosis problem. To improve the overall identification accuracy, to the best of our knowledge, this is the first attempt in applying ANN or SVM to similar application. Consequently, a properly trained ANN classification model can be a strong predictor for use in the LD diagnosis procedure. Furthermore, a well-trained ANN model can also be used to verify whether a LD diagnosis procedure is adequate. In conclusion, the author expects that AI techniques like ANN or SVM will certainly play an essential role in future LD diagnosis applications.

Kavita Jain et al. (2009) presented a straightforward Multi-Layer Perception (MLP) based ANN method for diagnosing LD and experimental results were tested based on curriculum test conducted by specialized educators. A single layer perception model is used to diagnose LD. The method is not only simple, straight forward and easy to replicate in huge volumes, but gives comparable results based on accepted detection measures.

Palacios et al. (2010) proposed to use a genetic cooperative–competitive algorithm for designing a linguistically understandable, rule-based classifier that can tackle dyslexia problem. The above mentioned algorithm is part of a web-based, automated pre-screening application. The main objective of the extended Genetic Fuzzy System (GFS) in the scope of this research was to obtain a Fuzzy Rule Based System (FRBS) from low quality data that can be used by unqualified personnel to detect whether a person has suspicious symptoms and then suggest consulting with the psychologist. This objective is not fully achieved, because the percentage of misclassifications is also high.

Abingeret al. (2014) introduced a novel therapy approach based on real-time measurement of patients' eye movements as they attempt to read words. More specifically, an eye movement contingent technique of stepwise letter de-masking was used to support sequential reading, whereas fixation-dependent initial masking of non-

central letters stimulated a lexical (parallel) reading strategy. A generalization to untrained items was only found in segmental readers after the lexical training. Eye movement analyses were also used to compare word processing before and after therapy, indicating that all patients, with one exclusion, maintained their preferred reading strategy.

## 3. RESEARCH GAP

Following points justify the need for research – a maiden attempt in this direction.

- Detection of dyslexia becomes very important to improve the learning ability which is carried out mainly by three persons namely Physicians, Parents and the Society.
- Physicians have an important role to play in the identification of dyslexia and associated risks.
- Dyslexia affects a growing number of individuals, and it is important for parents to recognize the early signs so they can better assist their children in getting the appropriate services.
- Dyslexia, identified and treated at the earlier stage can help the society at the greater extent to overcome the setbacks in their future,
- Dyslexic individuals can also show more competence with others when counseled in good manner,
- Dyslexia can often go undiagnosed for years, and causes a person unusual frustration and disappointment that can lead to greater academic struggles in the future.
- When the work is converted into an embedded system, it can be used in hospitals for early detection of dyslexia.

To avoid these kinds of problems this application is developed through our research work and it is most useful to the young generation. The implementation of proposed methodology is carried out in MATLAB 7.10.0.

## 4. SOLUTION

Awareness about dyslexia is not to the required level in India. As a result, many people lead their life without rectifying the defect. By understanding the intensity of the problem, here an attempt is made with the aim of detecting the dyslexia at the early stage.

- To help the individuals for diagnosing their learning disability at the earliest,
- To analyze the possibility of dyslexia detection only from the eye movements' signal,
- To develop a neural network based dyslexia detection method,
- To develop a dyslexia detection method based on swarm intelligence methods and introduces a transformation method for feature extraction,
- To measure eye movements' signal readings and feature selection by using Artificial Bee Colony algorithm (ABC) to improve dyslexia detection results,
- To show the results of proposed work based on the performance metrics like sensitivity, specificity, accuracy, precision, F-measure and P-value.

## 5. CONCLUSION AND FUTURE WORK

Researchers, neurologists, investigators, parents and teachers have developed various architecture models, simulated systems, prototypes for reasonably accurate prediction/detection of dyslexia. This review work discusses about conventional dyslexia detection methods, eye movements based dyslexia detection, feature extraction methods, feature selection methods, classification based dyslexia detection methods in a detailed manner. The present review work is devoted to aspects related to different writing skills and types of writing difficulties among dsygraphic children. Decades of research suggest with the purpose of interference & remediation is a necessary element of the education of children by means of Learning Disabilities on school and home.

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