Abstract: This paper describes the process of design and development of a prototype to automatically detect dyslexia and subsequent automatic customizations. The customizations offer changes in presentation of textual content in terms of text size, color, background etc. A prototype was developed following the universal design standards which could track the eyes of the users. The eye tracking data thus collected was internally analyzed to determine dyslexia in users. The prototype underwent user testing with multiple users with varying degrees of dyslexia. All the users also participated in a semi-structured interview to get further insights and opinions. The results thus obtained from the prototype testing and the semi-structured interview suggest ……….

Keywords: dyslexia, prototype-designs, web-application, eye-tracking, customization, automatic-detection

# Introduction:

Dyslexia is a commonly occurring learning disability which affects reading and spelling, due to the problems occurring in the brain functions related to auditory-linguistic processing (Landerl, Fussenegger, Moll, & Willburger, 2009; Policy et al., 2008; Rello & Ballesteros, 2015). Individuals with dyslexia also have structural differences in their visual systems in the brain(Policy et al., 2008). Dyslexia:

Dyslexia is a frequently occurring learning disability which affects reading and spelling caused by problems occurring in the brain functions related to auditory-linguistic processing. Dyslexia refers to a specific deficit in the acquisition of reading dependent upon cognitive deficits such as phonological deficit (Landerl et al., 2009). People with dyslexia need to invest significant conscious effort and resources on monitoring and balancing their attention which means that their performance is adversely affected by secondary tasks which can distract attention from their primary task(Nicolson & Fawcett, 1990). Dyslexia is also termed as a hidden disability due to the fact that it is particularly difficult to discover and many people remain undiagnosed. Along with this fact, dyslexia takes quite long time to get diagnosed as the diagnosis procedures are expensive and dependent on experts. It is made even more severe by the fact that dyslexia can have several implications depending on languages. There are languages with a variety of orthographies, which further impedes their learning capabilities. Dyslexics face language related issues due to factors such as orthography, phonology, morphology, lexicon and discourse (Rello, 2014). In the paper, “The Cognitive Deficits Responsible for Developmental Dyslexia: Review of Evidence for a Selective Visual Attentional Disorder”, it is concluded that, phonological disorder is not the sole cause of reading acquisition difficulties in developmental dyslexia. Therefore, Visual attentional deficit is considered to be the underlying cause of reading acquisition disorders in various numbers of dyslexia cases. Visual attentional deficits are not dependent on phonological deficits (Valdois, Bosse, & Tainturier, 2004). A growing amount of data suggest that a visual attentional deficit could contribute to reading impairments of dyslexic children. However, data suggests that the spatial attention deficit in dyslexia is not restricted to visual modality but extends to auditory information processing(Facoetti et al., 2003; Hari & Kiesilä, 1996). Hari and Renvall (2001) proposed the Sluggish Attentional Shifting (SAS) theory of dyslexia. According to SAS theory, visual attentional deficits should typically co-occur with phonological processing and phonological awareness deficits in developmental dyslexia (Hari & Kiesilä, 1996).

In this paper, we present a prototype which can automatically detect dyslexia in users and applies appropriate customizations for better readability of textual contents. It observes the eye movement patterns of the users in terms of number of fixations and the reading time which is further analyzed to determine if the user is dyslexic or not. Finally appropriate customization options are automatically applied to assist users with better readability of text which is also expected to increase comprehension.

In the first part of this paper, some relevant literature is discussed regarding relevant eye movement studies related to dyslexia and the customization options which can increase readability for people with dyslexia. Following this section, in the second part the process of prototype development is discussed. The third part consists of the discussion and finally a conclusion is drawn with possible future scope for improvements.

# Eye Movement Studies and Dyslexia

In this section, some previous eye movement studies which are relevant to our study in terms of dyslexia and reading difficulties are discussed further.

There have been several studies focusing on the investigation of cognitive activities based on eye movements (Hyönä & Olson, 1995). These studies suggest that the reading patterns of people with and without dyslexia differ in various ways which can be inferred through their eye movement patterns. In one study by Rayner, it is suggested that different aspects of eye movements such as shorter fixations infer better readability whereas longer fixations infer problems with readability caused by overload of cognitive processing. Therefore, there are various aspects of eye movement which are different in dyslexic and non-dyslexic individuals. Many studies have suggested that these eye movements are representative of reading disabilities. However, studies by Tinker (Tinker, 1946, 1958) and Rayner (Rayner, 1985, 1998) have quite strongly suggested that eye movements are not only representative cause of reading disability but are reflections of underlying problems which might be related to cognition.

In several non-reading tasks it has been shown that people with dyslexia have different patterns of eye movements than those without dyslexia(Eden, Stein, Wood, & Wood, 1995; Pavlidis, 1978). In one non-reading research by Eden et al. (Eden et al., 1995) showed that the eye – movement stability during fixation was worse in children with dyslexia in comparison to those without dyslexia. However, replicative studies of these researches have been inconclusive and do not necessarily show the same results as indicated from these researches. In reading studies conducted by several researchers it is shown that readers with dyslexia tend to process less parafoveal information during each fixation in comparison to the regular readers(Rayner, Murphy, Henderson, & Pollatsek, 1989; Underwood & Zola, 1986). These studies which include reading and non-reading tasks suggest that there is an obvious difference in the eye movement patterns of dyslexic and non-dyslexic populations. There are different eye movement patterns such as: saccades, fixation and regression. Saccades are the continuous eye movements made when reading or looking at objects. Within these saccades, our eyes have momentary fixation moments where they remain still for 200 – 300ms which are called fixations. Regressions are right to left movements or movements back to the previously read lines of text(Rayner, 1998).

Eye movement patterns of dyslexic readers tend to be different than those without dyslexia in terms of more frequency of fixations with longer durations, shorter saccades and more regressions (Adler-grinberg & Stark, 1978; Borsting, 2002; Eden et al., 1995; Lefton, Nagle, Johnson, & Fisher, 1979; Rello, 2014). The higher number of fixations are representative of dyslexia as dyslexics have relative more fixations than non-dyslexics(De Luca, Di Pace, Judica, Spinelli, & Zoccolotti, 1999; Hutzler & Wimmer, 2004). There have been previous researches regarding reading disabilities which have employed eye-tracking technologies. The data thus obtained have been employed in various studies regarding reading and information processing tasks(Rayner, 1998).

All these studies certainly suggest that dyslexia is not just a reading disability but the reading disability is just a tip of the iceberg. More importantly, these research finding suggest it to be a cognitive disability leading to reduced language processing capabilities which is seen on the surface as difficulty to read and understand text, languages etc.

# Content Presentation:

There have been previous researches to make text content accessible for people with dyslexia. In this section some previous studies have been discussed which were conducted to understand different text presentation conditions which might improve the reading capabilities of people with dyslexia.

The findings from previous researches suggest that dyslexics encounter problems due to complex words which are long and infrequent (Hyönä & Olson, 1995; Rello, Baeza-Yates, Dempere-Marco, & Saggion, 2013; Rüsseler, Probst, Johannes, & Münte, 2003). Therefore, text presented for dyslexics must contain simplified words which are in frequent use as well as easier to comprehend. In terms of presentation of text, font size and line-spacing play vital role in comprehension and readability of text. One of the major problems faced by people with dyslexia is the small font size of textual contents (McCarthy & Swierenga, 2010). There have been various studies which have suggested different font sizes ranging from 12 or 14 points to larger font-sizes for dyslexics (Al-Wabil, Zaphiris, & Wilson, 2007; Bradford, 2011; Dyslexia, 2012). Even in accessibility guidelines such as Web Content Accessibility Guidelines (WCAG) (Caldwell, Cooper, Reid, & Vanderheiden, 2008), dyslexia is placed under a part of cognitive disability without any specific guideline for presentation of text specific to needs of dyslexics even though previous researches have shown that presentation of text can have significant performance improvements (Gregor & Newell, 2000; Kurniawan & Conroy, 2007; Rello, Kanvinde, & Baeza-Yates, 2012). The findings of one study by Rello et al. showed that the font size of 18 points and above have significantly higher comprehension scores for dyslexics. The subjective readability increased with font-sizes at 18 or 22 points thus increasing the subjective comprehensibility as well (Rello, Pielot, Marcos, & Carlini, 2013). Similarly, line spacing also plays a vital role in readability and comprehension (Hillier, 2006). Line spacing is directly related to reading performance as narrow line spacing decreases readability of text. In previous researches, it is stated that line spacing between 1.3 and 1.5 to 2 lines is considered as well suited for better readability (Dyslexia, 2012; Rainger, 2003; Rello et al., 2012).

There are also various tools which have been developed to assist people with dyslexia to modify contents according to their needs. In one study, a tool called SeeWord is developed for MSWord which could improve the subjective readability of MS Word documents increasing the reading accuracy as well(Anderson, 2000; Dickinson, Gregor, & Newell, 2002; Gregor & Newell, 2000). Another project focused on a technology called MultiReader which could help people with dyslexia as well as visually or hearing impairments. It could interpret documents using various methods such as text-to-speech, subtitles, sign language interpretations for audio and video and audio descriptions of vido materials. However, it also possessed some usability issues when it was tested with 12 participants (Petrie, Weber, & Fisher, 2005). In another study by Kurniawan and Conroy, they tested different color schemes for reading online with 25 dyslexic users. They had to read five online text articles followed by questionnaires. The comprehension of dyslexic readers was poorer for complex articles however they were allowed to select their own color schemes therefore, the reading speed was not slower (Kurniawan & Conroy, 2007). Another study by Santana et al. developed an extension for Mozilla Firefox called Firefixia which is a tool which allows dyslexics to increase readability by customizing websites by changing font type, font color, font size, line spacing, character spacing and column width (de Santana, de Oliveira, Almeida, & Ito, 2013). Although there are various approaches toward making content presentation accessible for dyslexic users there is a lack of a technology which can merge two aspects of automatic detection of dyslexia and automatic customization of content presentation.

# How is our study different ?

Difficulties caused by dyslexia

Eye tracking technology

Prototype development

Future scopes:

Content changing automatically such as grammar, spelling etc.

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