

Improved Methods for Dyslexic People to Read Tabular-Structured Data Using Browser
Extensions

*This project aims to help dyslexic users read e-content, especially tabular-structured data,
by developing a tool to be added to the Google Chrome browser.*

2015

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Abstract

There is considerable evidence that coloured overlays address several reading issues faced by people with dyslexia. However, there is still a serious limitation in addressing dyslexic users' ability to read two-dimensional data structures. This project involves developing a tool that can be added to the Chrome browser to enhance dyslexic users' ability to read tabular-structured data on webpages. The tool creates a virtual coloured overlay for the webpage. The overlay contains two rows with a high level of transparency. The content of the corresponding table header and the row to be read on the webpage can be seen through the background, and the rest of the webpage's content is hidden. The idea for this tool came out of the first phase of this project, which focused more on understanding target users' needs, issues, treatments, support systems and standards. The idea is novel and is improved by adopting a suitable human computer interaction method called User-Centred Design, which will be explained along with ways to implement and test the tool. This tool was evaluated by a group of dyslexic volunteers. The data collected from the study was composed of quantitative data from screen and mouse recorders and qualitative data from interviews. The outcome of the study shows that the tool supports users' focus and is helpful for users with dyslexia when reading tabular-structured data.

DECLARATION

No portion of the work referred to in the dissertation has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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Acknowledgement

I would like to express my deep gratitude to my supervisor, Dr Mary McGee Wood, for her advice, enthusiastic encouragement, supervision and her availability during the development of this project. Although I had some hard times during the year since I birthed my first child and experienced motherhood for the first time, she understood my situation and helped me stay on schedule.

I would also like to thank everyone in the Manchester Dyslexia Self-Help Group for their participation in the project, for sharing their time and experience, for welcoming all the questions I asked and for providing a warm and friendly atmosphere. Special thanks goes to the head of the group, Mr Roger Broadbent, for his support and cooperation.

My thanks also extend to King Saud University for giving me the chance to study my MSC degree at The University of Manchester and for its support.

Finally, and most importantly, I would like to thank my husband for his support, encouragement and patience. I thank my daughter for her kicking and first smiles. She gave me the love, power, happiness and passion to do my best. Deep thanks to my parents for their faith in me and allowing me to be as ambitious as I wanted.

1. Introduction

This chapter aims at introducing the dissertation by showing the project scope and motivation, aim and objectives, deliverables and the dissertation's structure.

1.1 Project Introduction and Motivation

People with dyslexia have specific learning difficulties related to the skills of reading, writing and understanding, which may pose numerous barriers to their education. The reading process involves not only the ability to pronounce and identify words correctly but also includes decoding the text and obtaining its meaning. Individuals with dyslexia who struggle to recognise letters correctly therefore may have to expend more effort to read compared to people without dyslexia [1]. Much research shows that assistive reading software enhances the reading rate and comprehension of individuals with learning difficulties (see Section 2.3).

This project provides a tool that makes tables of web data more readable to users with dyslexia. Many significant motivations triggered this project, one being that it will benefit dyslexic users, who represent a large group. Approximately 10% of the British population are dyslexics, as are 10–17.5% of the U.S. population. Moreover, studies have proven that assistive tools for dyslexia are useful for others [2] [3] [4]. Another motivation was enhancing web accessibility and achieving universality for everyone regardless of disability; the web is an especially important resource for obtaining educational, medical and other sorts of information. The United Nations' guidelines claim web accessibility as a human right, and the Equality Act of 2010 classifies dyslexia as a disability. In addition, this project represents no similarity to previous research or existing applications. The findings of this project may open a door for more research and assistive applications.

1.2 Aims and Objectives

The aim of this project is to develop an assistive tool for use by individuals with dyslexia that will enhance their reading ability with e-content, especially two-dimensional data structures.

The objectives of this project are as follows:

1. Gain insight into innovative solutions for providing support to individuals who have learning disabilities such as dyslexia.
2. Understand the needs and requirements of users with dyslexia.
 - 2.1 Review the guidelines and standards for designing an accessible system for users with dyslexia.
 - 2.2 Review the learning-difficulties psychology research and methods to understand the reading difficulties faced by this population.
 - 2.2.1 Understand how these difficulties affect the reading process and distil the findings, including descriptions of key problems.
 - 2.2.2 Understand the current strategies or treatments used for improving reading performance and identify those to be considered for implementation.
 - 2.3 Gather requirements from dyslexia specialists or parents, either by surveying key stakeholders or by conducting interviews. Resources related to reading tabular-structured data are practically unavailable.
3. Adopt appropriate Human Computer Interaction (HCI) methods for designing and developing system-specific considerations for dyslexia. The aim is to involve the stakeholders in the design and approach considered, such as User-Centred Design (UCD), for people with disabilities.
4. Design and develop the tool for helping dyslexics read tabular structured data in Google Chrome.
5. Evaluate the effectiveness and efficiency of the assistive tool, working with the Manchester Dyslexia Self-Help Group (MDSHG) [5], and ensure that it improves reading performance for people with dyslexia.

1.3 Description of the Result

This project will result in a tool, plug-in or extension that enhances browser reading performance in general and the performance of reading tables in particular for people with dyslexia. The tool is an overlay on a webpage and has customised colours and transparency. This overlay hides the webpage's content except for a row and its header. Row height is customisable using arrows in each row, and a row's position changes by using different options. The position of the first transparent row, for example, can be selected using the right click menu, while the second transparent row moves on mouse-over by clicking the related option before (see Figure 1). These features were added according to stakeholder needs, which were found through a suitable HCI design model (UCD).



Figure 1: The tool interface.

Back	Alt+Left Arrow
Forward	Alt+Right Arrow
Reload	Ctrl+R
Save as...	Ctrl+S
Print...	Ctrl+P
Translate to English	
View page source	Ctrl+U
View page info	
Move The First Transparent Row Here	
Inspect element	Ctrl+Shift+I

Figure 2: The right-click menu showing the option that moves the first transparent row.

Few previous efforts have focused on this area, making the requirements and findings identified from evaluating this tool significant.

1.4 Report Structure

Section 2 presents an overview of dyslexia and the technologies used to improve the reading skills of people with dyslexia. Section 3 describes the approach used in designing this tool (UCD), the Google Chrome extensions architecture, the evaluation methodologies and the project plan. Section 4 describes the interface design and the implementation details. Section 5 is concerned with how the tool was tested using unit testing environments and which main functions were tested. In addition, this section shows the evaluation process that was conducted with the target users as well as the results and the findings of the evaluation. Finally, Section 6 draws the key conclusions and presents some ideas that can be implemented to enhance the tool or develop new applications in the future.

2. Background

Much research has been conducted to understand dyslexia from the psychological, educational and technical perspectives. This chapter aims to describe the scope of this project by reviewing related approaches and supporting research and work. It begins with an overview of dyslexia and its causes, symptoms and traditional treatment. The remainder of the chapter is concerned the technologies used for dyslexia, the benefits of assistive technologies and some examples of systems designed to enhance the reading ability of dyslexic individuals. In addition, it reviews key guidelines for designing accessible systems for those with dyslexia. The final section focusses on reading tabular-structured data.

2.1 What is Dyslexia?

2.1.1 Definition of Dyslexia

Ever since the first case of dyslexia was diagnosed in 1887, various attempts have been made by many authors and organisations to define it [3]. Apparently, differences amongst scientific backgrounds, such as in the academic or medical fields, are some of the main reasons for these various attempts. According to Reid (2007) [6], dyslexia is a different way of processing information, and it occurs in people in all ages. Individuals with dyslexia have difficulty with reading, writing and some cognitive skills such as memory, time management and processing speed. The severity of these difficulties differs from one person to another. Some dyslexic people also have visual stress and phonological difficulties. These individual differences should be recognised by teachers to understand their effects on learning and to find suitable ways of dealing with dyslexic students.

Read Regular is created without copying or mirroring shapes. Therefore the frequency of repeated shapes in a text is decreased. This results in a minimum chance of visual distortions (swirl-effect). The aim is to create interesting typography that will maintain the readers' interest and will prevent them from getting bored or frustrated. Diversity in text knows many variations. We must understand the fact that typography for a novel is different from a magazine or a publication for education. Even so a novel has the potential to be clear and interesting. This can be achieved in any level of creativity, thinking on type size, leading, the amount of words on a sentence and the character/paper combination.

Figure 3: An example of visual stress

According to the International Dyslexia Association [7], dyslexia involves difficulty recognising words fluently; problems in spelling and decoding are often associated with it.

The cause is a lack of the phonological component of language. This leads to a lower level of reading ability, including comprehension and fluency. Lack of reading practice leads to less knowledge and a smaller vocabulary. Dyslexia is an issue which affects the person throughout his or her life. The impact of dyslexia on an individual, however, can be decreased by adopting suitable teaching methods.

Samuel Torrey Orton (1920) provided another definition of dyslexia, namely “cross lateralization of the brain”. This means that the left side of the dyslexic person’s brain does what the right side is supposed to do and vice versa. Later, Orton introduced another definition – “mixed hemispheric dominance”, meaning that *sometimes* the right side of the brain does what the left side is supposed to do and vice versa. Being dyslexic does not connote stupidity or failure. Famous, successful people who were geniuses despite their dyslexia include Walt Disney, Hans Christian Andersen and Albert Einstein [8].

2.1.2 Causes of Dyslexia

Many studies have been conducted on the causes of dyslexia. The main reason for its emergence, however, is still not clear. According to the United Kingdom’s National Health Service (NHS), it is widely accepted that the cause is genetic, and that dyslexia is inherited from the parents. The chances of having dyslexia increase if an individual’s grandparents, uncles or aunts have dyslexia, and with twins, if one of them has dyslexia. Research has shown that there are differences in the brains of individuals with dyslexia. These differences cause problems which affect phonological processing [9].

It is believed that hearing impairment at early ages can also be a cause of dyslexia. Some children who have frequent flu infections in their first years may have what is known as “glue ear”. This condition cannot easily be discovered by parents and may lead to hearing difficulties. The consequences of delay in diagnosing these difficulties are that the brain cannot develop and create links between word concepts and the correct pronunciation of the word. Another consequence is the delay of phonological awareness, which leads to lifelong problems if there is no surgical intervention, such as inserting a small tube in the child’s ear to drain off the fluid [10].

2.1.3 Signs and Symptoms

People with dyslexia have specific symptoms which differ from one individual to another. Some of these appear in childhood, such as delays in speaking and difficulty with learning letters. The signs change later but do not completely disappear. Adults with dyslexia have

such symptoms as poor spelling and handwriting, difficulty with taking notes and copying, problems with writing organised essays and difficulty remembering sequences of characters such as telephone numbers [11].

According to Davis [8], dyslexics suffer from various symptoms which are the result of sensory distortion, such as with sight, hearing, movement, balance and time. Some of these symptoms involve seeing letters reversed, moved or disappeared, skipping lines or words during reading and writing and ignoring capital letters and punctuation.

2.2 Current Strategies and Treatment

Although dyslexia is a lifelong condition which cannot be cured or fixed, there are many learning strategies which dyslexics can use to overcome many of their difficulties. The effectiveness of these strategies depends on the specific difficulties the individual faces and the stages when these difficulties are faced. Therefore, the impact and severity of the disability on individuals should be determined before adopting any strategy. This assessment can be made by a specialist or doctor in one-on-one sessions [12].

Most existing strategies are used to help younger dyslexics to improve their understanding of written words. It is believed that developing the ability to read and write with assistance at an early age (ideally before seven or eight years old) leads to long-term improvement in reading and writing skills without assistance [13, 14]. Therefore, children with dyslexia always need more time and effort to develop their skills compared to other children.

Learning to read is not a simple process, and it is especially difficult for dyslexics. Reading requires the use of both linguistic and cognitive skills. Current learning strategies which are used to help dyslexics read more fluently and with a deeper understanding focus on decoding and phonological skills. According to Snowling et al. [15], decoding is the ability to map phonology (the sound corresponding to a word) to orthography. Decoding depends on abilities which include knowledge of letters and phonological skills. There is some evidence that ease in learning to read depends on the language's characteristics, such as the links between the visual symbols written as a collection of letters and the pronunciation of those letters. For example, in English, there can be a confusing correlation between letters and sounds, such as in "ch" which is pronounced differently in chair, machine and Christmas.

Strategies for learning how to read are widely used with all children, not just those who are dyslexic [13]. For example, phonic or multi-sensory strategies may be employed.

The phonics reading strategy is one method recommended by the National Reading Panel in the United States; it has been used for a long time. Phonics employs the correspondence between letters and sounds to learn words. The idea behind this strategy is to break a word down into small units called phonemes and to combine these sounds to show the relationship between the sounds and letters. According to Grogan (2012), a causal connection has been proven between phonics reading techniques which emphasise letter sounds and improved reading skills. He claimed that pronunciation plays the major role in providing long-term benefits for students. Thus, he suggested that the student's language skills in general will improve if pronunciation and reading activities are combined [16].

A multi-sensory strategy is one of the most effective methods used with dyslexics [17]. The idea underlying this strategy is to stimulate more than one sense in learning words, which means that dyslexics can learn how to read words by seeing, hearing, touching, speaking and smelling. Moreover, they may perform activities related to the meaning of a word, such as moving and pushing. In this way, they connect the visual representation of letters, sounds and the hand moving to write them. One of the strengths of this method is its ability to hold the attention of a dyslexic child, especially since it is difficult for dyslexics to focus during the learning process [18].

The above strategies are known as traditional methods. The research has shown that using these methods brings moderate success in learning, and the use of technology further enhances that success. The use of technologies with these methods makes the learning process more fun and deepens dyslexic children's understanding. These technologies include interactive devices such as whiteboards and multimedia tools involving video, audio, animation and graphics.

2.3 Technological Support for Dyslexic Users

Dyslexics need extra support to overcome weaknesses which have been part of their lives ever since they were children. Teachers cannot provide this extra support alone, and there is a need to find alternatives. The use of technology offers some benefits because existing

features can support and assist dyslexics. Such features include photos, animation, colours, sounds and multi-sensory experiences. This section will provide an overview of the effective use of technology to assist those with dyslexia in reading. In addition, some examples of technology which is widely used by dyslexics will be given.

2.3.1 The Benefits of Using Technology

Technology can be used for different purposes. For instance, it may provide assistance with some functions which it may be difficult or impossible for individuals with special needs to perform. Products which offer these functions are known as assistive technologies. Assistive technologies designed for reading do not focus on developing specific skills or teaching a complex subject; rather, they aim to help dyslexics to work around their difficulties and make the reading process easier [19]. According to a study by Linda Hecker et al. (2002), assistive technologies allow a student with learning disabilities to better deal with reading difficulties and read for longer times because they render reading less stressful and difficult. In addition, it is believed that using assistive technologies encourages learning-disabled students to be more independent, which leads to increased confidence and motivation to learn [20].

There has been much research concerning the effectiveness of assistive technologies for people with dyslexia. The goal of this research is to show the role assistive technologies play in minimising dyslexics' weaknesses in reading, writing and other skills. In terms of reading, a computer reader with various features has been a common tool used in various studies. For example, Elkind et al. (1996) [21] studied the impact of using a speech synthesis programme as a compensatory tool for dyslexic adults. The significant finding of this study was that students remained engaged longer in a reading task when they used a computer reader. In addition, the rate of reading and comprehension was enhanced for most participants. Similarly, Torgesen and Barker (1995) [22] reported that there was significant improvement in the phonological and decoding abilities of those who suffered from reading disabilities.

Paraskevi et al. (2010) [23] conducted a one-year study aimed at finding the benefits of using these technologies to overcome reading difficulties amongst speakers of English as a second language (ESL). They also used text-to-speech software programmes (ReadPlease

and TextAloud) with the ability to read digital text and highlight words as they read. In addition, this software allows font size and voice type to be adjusted as required. This study was applied to college students who were categorised into three levels according to psychometric cut-off scores. Each student level was given a text with a suitable degree of difficulty. The findings of this study indicated that there was a significant improvement in their reading ability. Their reading was measured by having them answer questions on paper and by using assistive software after reading a text.

Another example of using assistive software for ESL speakers comes from a study by Chiang and Liu (2011) [24]. They evaluated the effect of using Kurzweil 3000 as assistive software for dyslexic high schools students from Taiwan. This is a screen-reader programme with features which include highlighting and sticky notes. The students used the programme for two weeks after having a short training session to make sure they understood how the software worked. The interface was in English for Taiwanese students with limited grasp of the language. In this study, 11 out of 15 students reported that this system helped them with reading and spelling, despite the short duration of the intervention. One of the main advantages these participants identified was independent reading. In addition, one of the participants was able to better understand the meaning of English words when listening to them using the sounding-out feature than by reading them.

From previous research, it can be argued that there is considerable evidence that assistive technologies can be part of a long-term solution for those with disabilities. As far back as 1988, the United States enacted a law known as the Technology-Related Assistance for Individuals with Disabilities Act. One of the main goals of this act was to provide financial support for states to create and develop assistive technologies for those with disabilities [20].

2.3.2 Assistive Technologies

There are many examples of effective assistive technologies which are available for people with dyslexia. These technologies can be classified according to the type of difficulty which an individual experiences, since each type has different requirements and methods of support. For example, the use of a spell-checker helps with writing, task management systems help with organisation and audio recorders help with listening and memory weakness.

Assistive technologies are widely used to enhance reading ability, which is a large part of the overall goal of this project. Such technologies can be categorised as follows: coloured overlays, text-to-speech and font customising systems.

2.3.2.1 Coloured Overlays

Coloured overlays are coloured filters used to reduce readers' visual stress, which can lead to headaches and reading difficulties. They consist of transparent plastic sheets placed over texts. They change the colour of the paper without affecting the clarity of the text. Each person has a favourite colour that he or she uses to facilitate reading. These sheets are usually the size of a full A4 page or a six-inch ruler. An example of such a product is shown in Figure 4 [25]. One of the advantages of using these products is that they are comfortable to use; the reader can use them for reading texts when they are on the move. In addition, these products are proven to address various problems resulting from poor visual processing, such as an inability to notice whole words or skipping lines, words or sections [26, 27].



Figure 4: An example of coloured overlays

These coloured filters can also be used as glasses, lamps or physically added to a computer screen to change the desktop colour [28]. Other applications have been developed to add floating transparent backgrounds to desktop screens.

- **The Colour Overlay Extension**

Colour overlay [29] is an extension that places floating backgrounds on webpages viewed through the Google Chrome browser. It allows users to change the colour of the background and to choose a suitable degree of transparency. It is a simple and easy-to-use tool. This feature is available in Google Docs, but it does not support some types of documents, such as PDFs.

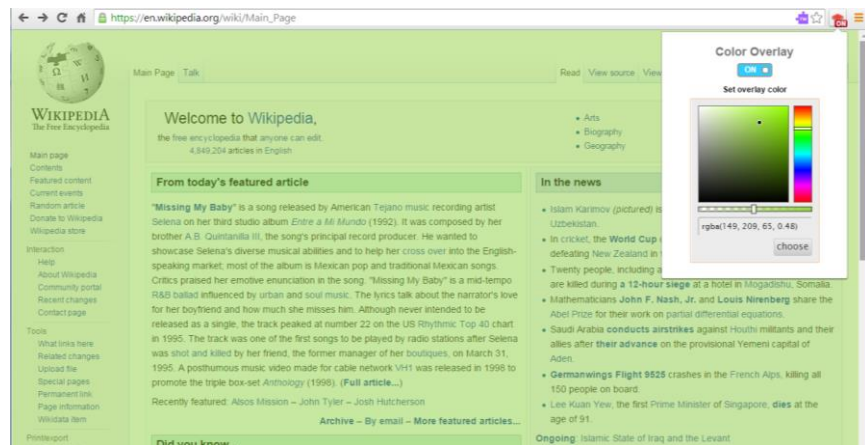


Figure 5: A screenshot using a coloured overlay tool

- **ReadEZ Virtual Overlay**

ReadEZ Virtual Overlay is a desktop application which was developed by ReadEZ. It works with all PCs and can adapt to many versions of Windows. This application allows users to change the desktop background colour by adding a floating background. The colour of everything behind this background is changed. ReadEZ also allows users to change their background colour by selecting a colour from the available colour options or by uploading their favourite colour. Users may also change the overlay size and transparency. The tool also offers the ability to move the overlay background. In addition, it provides the ability to change the font colour based on whether a Microsoft Word, Excel or other type of document is being viewed [30].



Figure 6: A screenshot of the ReadEZ virtual overlay application

2.3.2.2 Text-to-Speech Software

Text-to-speech (TTS) is one of the main assistive reading systems used by people with learning difficulties. It converts normal text to speech. The resulting audio can sound human-like, and the voice can be customised to be either male or female. The key benefits of using TTS were summarised by Elkind and Elkind (2007) [31]. One of these benefits is endurance. Dyslexic individuals were capable of reading for a longer duration when they used this tool, as mentioned earlier in this section. The researchers indicated that its use is capable of increasing reading speed, improving comprehension and sustaining the attention of those who suffer from attention disorders. Finally, TTS can provide writing assistance. There are many examples of assistive technologies which use this feature, such as Read & Write, ClaroRead, What You Need Now (WYNN), reading pens and others.

- **Read & Write (Extension by Google)**

Read & Write is a collection of applications used to support users on any device. These applications can be installed on Mac or Windows PC, iPad or Android and as an extension on the Chrome browser. The toolbars on all of these platforms provide the similar functions. The one which is most related to the developed tool is the Google Chrome extension.

The Read & Write extension (plugin) was developed for dyslexic users by TextHelp Ltd. This extension can work with webpages viewed through Chrome and some file types in Google Drive, such as Google Docs and PDFs. It provides assistance for students with

learning difficulties by offering several powerful and supportive functions. For example, selecting a text will cause it to read that text loudly, or highlighting a word within a sentence will cause it to read the entire sentence. Both the speed of the audio and the voice type can be adjusted using a settings window. The audio can also be translated to other languages. In addition, a user can find the meaning of a word using a text- or picture-based dictionary. This function may help dyslexic learners to better understand meanings. A text can be highlighted in any one of several colours. This highlighted text can be copied and used in other documents. This function allows users to create separate files containing summarised text. Another feature is the ability to simplify a webpage by creating a new page that contains only the text, which can then be enlarged or reduced. Any images and backgrounds are removed, making the text easily customisable [32].

This tool is user-friendly, and its functions are clearly represented in a toolbar. It also adopts a multi-sensory approach by allowing users to read and listen to the highlighted words. Furthermore, users can read and see the meaning of a word using the dictionaries that are provided. The efficiency of some of these features, such as simplifying a page, depends on the web developers who coded the webpages. Any bugs, syntax mistakes or violations of web access rules may negatively affect the features provided.

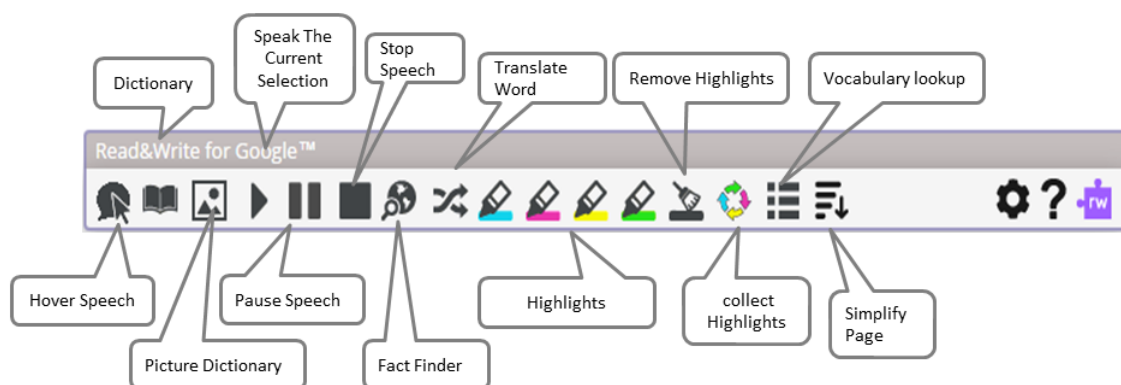


Figure 7: The floating toolbar for the Read & Write extension for Chrome

- **ClaroRead (PC Version)**

ClaroRead [33] is simple software aimed at helping users with dyslexia to read and write independently by providing some features displayed in the floating tool bar. These features

include highlighting text, font options, TTS, focussing on text as it is spoken and ScreenRuler. ClaroRead produces a high-quality voice with different accents and languages. It can read texts online and offline, including web browsers, email, PDFs, Microsoft Word and more. The text can be saved for later playback, sent by email or SMS message.



Figure 8: ClaroRead floating tool bar

The screen rulers includes three modes, namely ruler, underline and overlay mode. These modes are displays in Figure 9. The ruler mode is used to view a part of screen, while the underline mode helps those who have difficulties tracking a line of text and the overlay mode assists those with visual stress. The users can change the size, colour and opacity of the ruler. ClaroRead can work with Windows and Mac versions, as well as iPad and iOS apps.

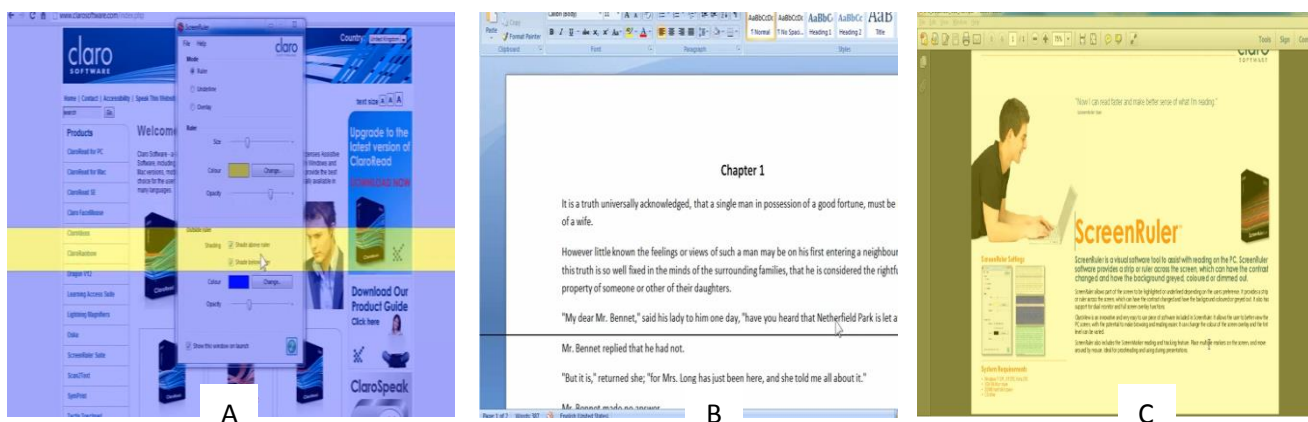


Figure 9: The different ruler modes used in ClaroRead: A) ruler, B) underlined and C) overlay.

- **WYNN**

This desktop application was developed to support users with reading or writing difficulties. It takes text and generates accessible files with several features. Text can be uploaded from a computer file and then imported to the WYNN programme. Alternatively, the user can scan a printed text and convert it to an electronic text.

There are two version of WYNN, namely Wizard and Reader. They have the same functions except that Wizard has scanning capability, while Reader does not [34]. Their features include reading aloud, highlighting, note taking, spell-checking, customising fonts and accessing a dictionary and a thesaurus.

This application also allows users to insert bookmarks, text and voice clips into a document. The system adopts a multi-sensory approach which benefits students of various ages. It can also be used by teachers. One of the features is a teacher lockout function. This allows teachers to limit access to the dictionary and spell-check, for example during exams.

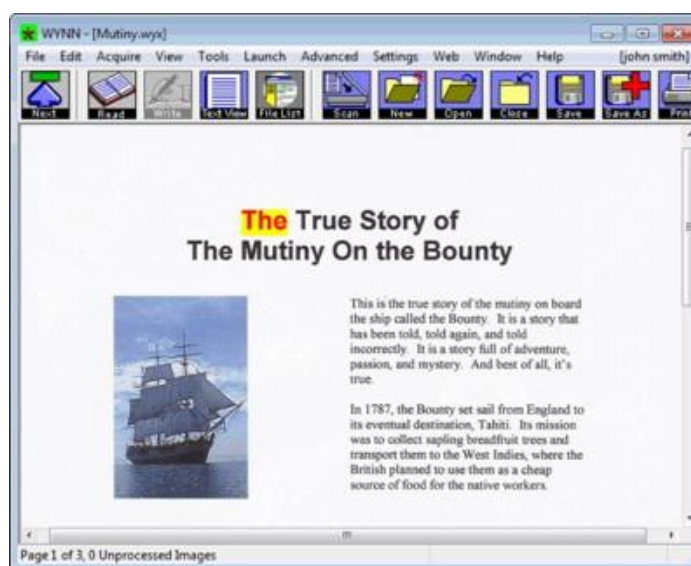


Figure 10: A screenshot of the WYNN system [35]

- **Reading Pens**

Scanning or reading pens are another assistive device used by dyslexics. The pen can scan a small number of typed words and then read them aloud. In addition, some of these pens can scan a word, pronounce it, display it in large letters and then provide its meaning [36]. One benefit of this device is that it can be used on paper. In addition, the ease of holding it encourages a user to use it everywhere.



Figure 11: An example of a scanning pen sold by Assistive IT

2.3.2.3 Font Customizing

Visual presentation plays an important role in the accessibility of a text for individuals with dyslexia. Rello and Baeza-Yates (2013) [37] conducted a study with 48 dyslexics to determine how font type affects reading performance. They measured the reading comprehension of participants by asking them questions related to the text they had read. Moreover, an eye-tracker (Tobii) was used to assess how participants dealt with a given text. The findings of this study indicated that font styles have an impact on reading and fixation durations. The authors recommend avoiding such font types as Arial It and italics.

Assistive font technologies can be classified into two basic types. The first is a special type of font designed for dyslexics. The second is a technology used to change or customise text so that it is increasingly readable for dyslexics. Below are examples of each of these two types.

- **Fonts Designed for Dyslexic Individuals**

Several types of fonts have been created to help dyslexic readers; these include OpenDyslexic, Dyslexie, SylexIad and Read Regular. Open Dyslexic is the only free and open-source font. It is also integrated into many devices and applications, and includes bold and italic styles. According to the creator of this font [38], each letter is represented with a heavy bottom to better indicate direction and thus help dyslexics to correctly identify each character. The font designers claim that this font helps dyslexic individuals read better. Rello and Baeza-Yates (2013) [37], however, demonstrated that the use of this font did not positively or negatively affect readability for dyslexic individuals.

This is an example of the Open
Dyslexia typeface

Figure 12: An example of the Open Dyslexic font

- **Applications which Customise Fonts for Dyslexic Individuals**

It is clear that dyslexics have special reading requirements due to their reading difficulties. The requirements of this population, however, differ amongst individuals [39]. As a result, tools need to be customisable to ensure that text is readable for everyone. An example of such a tool is SeeWord.

In 1999, Georg and his colleagues developed SeeWord as part of the human interaction research being conducted at the University of Dundee. This is word-processing software designed to help dyslexic individuals read. This programme provides a customisable system interface and various features related to textual representation. For example, users can change the font size, font colour and background colour, as well as the space-length between words, characters and paragraphs. In 2012, twelve dyslexic individuals evaluated this software and provided feedback on their experiences using a think-aloud approach. They tended to prefer large fonts and large spaces between words and characters. In addition, the participants preferred particular colour combinations. These findings opened the door for more research and therefore more solutions [40].

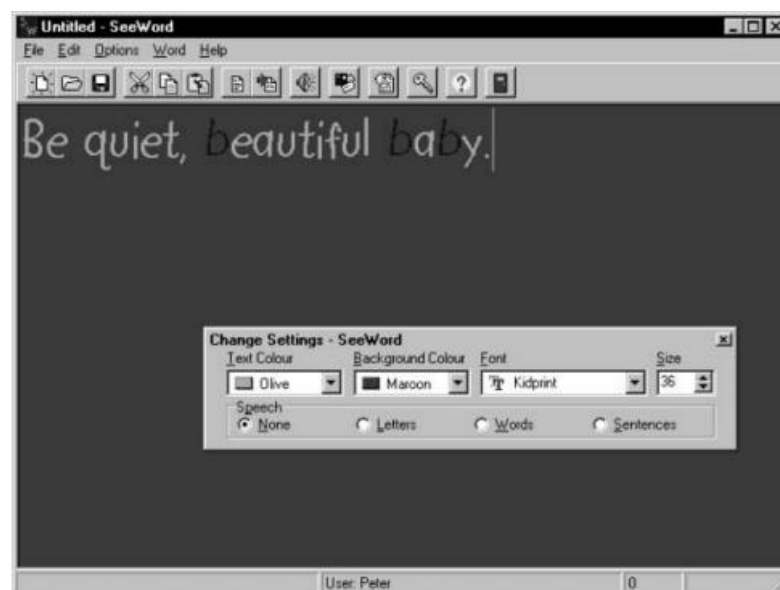


Figure 13: A screenshot of the SeeWord application shows how a text is displayed [41]

2.4 Guidelines and Standards for Accessible Systems

Accessibility refers to equality, in which the ability to understand, interact, navigate and access the Internet or any application is available to everyone regardless of any disabilities. Developers play a major role in achieving accessibility for applications or webpages by designing interfaces which meet users' needs. Compared with other groups of people with special needs, few usability studies have been conducted to understand dyslexic individuals' needs, especially those related to web accessibility [2, 3]. There is, however, a considerable number of resources and guides which should be followed. Increasing accessibility is helpful for all users, not only individuals with dyslexia [2, 3].

The British Dyslexia Association has introduced some recommendations to improve electronic readability for dyslexic people [42]. First, the use of white backgrounds should be avoided because of high brightness, which may lead to apparent moving or blurring of words. Dyslexic individuals have different preferences for colour; what is good for one may not work for others. Providing a selection of colours therefore addresses one of the key problems encountered by dyslexics [42]. In addition, it is advisable to use suitable font types, such as sans serif typefaces. The distance between words is also important. Furthermore, the font size should be sufficiently large (12- to 14-point or larger). Moreover, some font formatting may negatively affect reading ability, such as all capital letters, italics and underlining. The width of reading lines can also affect readability for dyslexics. Narrow columns, such as in newspapers, should be avoided, as well as long lines (longer than 60–70 characters).

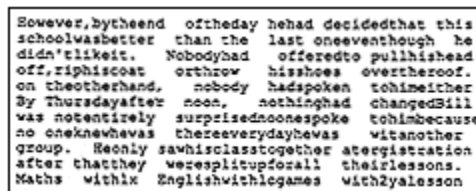


Figure 14: How some dyslexic users see high-contrast text, such as black and white [39]

A user study conducted by Rello et al. investigated a set of guidelines for text presentation in relation to users' preferences and fixation duration [2]. They prepared questionnaires and interviews to identify users' preferences, while an eye tracker (Tobii T50) was used to

measure fixation duration. The study involved a group of 22 dyslexic participants ranging in age from 13 to 36 years. The participants were asked to read 36 small texts on different layouts while being monitored by an eye tracker; they then filled out the questionnaire. The study found that the use of greyscale to change brightness did not help dyslexics as much as the use of colours. The favoured pairs of colours (foreground/background) were yellow/black, white/blue, cream/black, white/black, yellow/blue and light mucky green/dark brown. The study also indicated that the preferred font size was 26 points, which was the largest option, confirming that dyslexics prefer large text. It also showed that users preferred spaces between paragraphs of two lines, leading of about 1.4 lines and standard spacing between characters. The study also revealed that users do not prefer long lines, with 77 characters per line as the preferred choice.

As mentioned above, screen-readers are widely used as an assistive technology for dyslexic individuals. Thus, some factors must be taken into consideration to make content accessible for screen-readers. Tables should be used only for tabular data, not for layout. Using tables for layout makes the reading process by the screen-reader more difficult and less accurate [43]. In addition, some symbols cannot be read correctly by screen-readers, such as +, – and \geq . For example, some screen-readers present a hyphen instead of the minus symbol (2-2 rather than 2–2). Moreover, the use of commas, full stops and semicolons is important to separate sentences and clauses from each other.

2.5 Tabular-Structured Data for Dyslexic Users

It is clear from the previous sections that people with dyslexia consider reading linear text a significant difficulty. They face various reading problems, such as seeing letters move or skipping lines and words. These problems might increase when reading two-dimensional data consisting of rows and columns, because such data typically require additional effort to extract information; the more rows and columns, especially in large tables, the more difficult it becomes. Reading tables of data may therefore also require additional supportive technologies designed for dyslexics. However, as of yet, no technical solutions have been provided or supportive research conducted. This project attempts to bridge this gap by providing a possible solution which could help dyslexics to deal with tabular data.

2.6 Summary

This chapter presented a different definition of dyslexia and its signs, symptoms and causes. Although the main cause of dyslexia is not clear, there are many learning strategies used to reduce the severity of reading difficulties experienced by those with dyslexia. These strategies and some of the available assistive software were discussed in this chapter. There is considerable evidence to show that assistive software support can help readers with dyslexia. Some of this evidence was presented in the present chapter. The assistive systems used to enhance the reading process for those with dyslexia were classified into three parts, namely coloured overlay, TTS and font customisation. These were described with some examples. In addition, some of the guidelines and standards were discussed to set a vision of how an accessible system for dyslexic users can be created. Finally, to the best of our knowledge, there has not been any related software or research conducted to discuss the difficulties faced by dyslexics when reading tabulated-structured data. The next chapter will show the method used to identify the real requirements for those with dyslexia.

3. Research Methodologies

This section discusses the method adopted for designing and developing the system—the UCD approach. The implementation environment and the structure of Chrome extensions are also explained.

3.1 User-Centred Design

The UCD method was implemented during the analysis, design, development and evaluation stages of the system to ensure that it met target users' needs and provided the appropriate functionalities. The primary reason behind the use of UCD was to understand users' needs without their active involvement in the process. The international standard, ISO 13407[44], was followed in the system. This standard provides design guidance for UCD throughout the system life cycle.

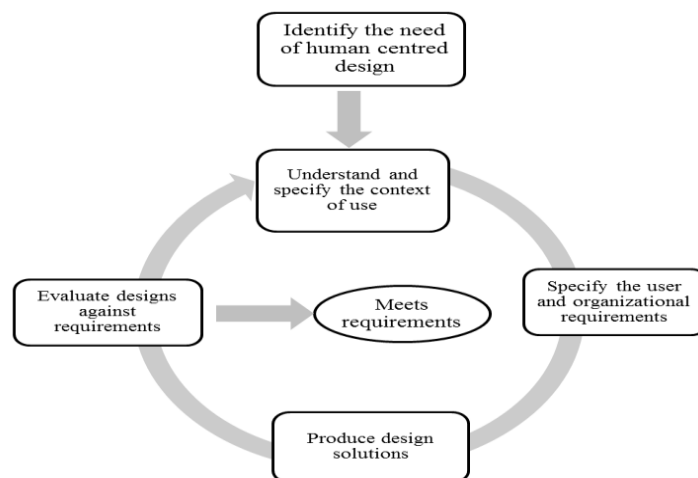


Figure 15: The UCD life cycle.

3.1.1 The need for UCD (Why?)

Identifying the need is the first stage of the UCD life cycle. Several reasons exist for adopting UCD in this project; one is that the target users are dyslexics. Designing a program for users with different experiences and abilities can be a challenge. In addition, using UCD decreases development costs by minimising unexpected changes. To the best of my knowledge, no background research or software address the difficulty that individuals with dyslexia have in reading tabular data.

3.1.2 The UCD Cycle (What?)

The UCD approach includes four main components, as illustrated in Figure 15. After identifying the need for adopting UCD, the flow of activities should be as described below:

- Understand and specify the context of use.

This tool is to be used by adults with dyslexia. They can access the tool without assistance and use the system to enhance the readability of tabular data structures.

- Specify the user and organisational requirements.

The tool should be simple, accessible and easy to use. Its requirements were determined via different avenues, including interviews with focus groups and domain experts, and considering accessibility guidelines and existing related systems.

- Produce design solutions.

This activity considered the applicable guidelines for accessibility and designing low-fidelity prototypes (paper-based, as shown in Figure 16), which were subsequently examined by a focus group. The tool conducted walkthroughs of design solutions, which were evaluated by target users.

- Evaluate designs against requirements.

The focus group examined a set of system designs and the control window to verify whether they met the design requirements. The users' feedback was adopted, and the system life cycle was started again.

The image shows two low-fidelity prototypes. The left one is a table with 6 columns: ID, Name, Course, Marks, Grade, and Status. It contains 8 rows of student data. The right one is a complex table titled 'Table 24: Total Turnover Rate by Age and Gender Percentage (as at 2013 year-end)(1)'. It has multiple columns for age groups and gender percentages, with a total row at the bottom.

ID	Name	Course	Marks	Grade	Status
1	Jack	Software Engineering	60	C	Fail
2	Bill	Software Engineering	90	A	Pass
3	Mirfaeen	Multivariate Calculus	34	D	Fail
4	Steven Shawmer	Software Architecture	58	D	Fail
5	Ruby Jason	Relational DBMS	70	B+	Pass
6	Mark Dyne	PHP development	34	D	Fail
7	Philip namdaf	Microsoft Dot Net Platform	78	B	Pass
8	Erik Bawn	HTML & Scritoine	87	A	Dacc

Figure 16: Samples of the first low-fidelity prototypes.

3.1.3 Applying UCD to This Project (How?)

UCD activities take place in each stage of a system life cycle. In this project, these activities took place in the analysis, design and development stages.

3.1.3.1 Analysis Phase

The analysis stage followed many steps, such as securing a good understanding of target users and their cognitive abilities and difficulties, attitudes and behaviour. In addition, meetings with target users helped set the vision. These users included actual end-users and domain experts in the MDSHG. The last step in the analysis stage involved reviewing the related systems and assistive products designed for users with dyslexia.

3.1.3.2 Design Phase

The design phase started with brainstorming for design solutions. That was followed by the creation and evaluation of low-fidelity prototypes with dyslexic users.

A. Looking for the best solution

At an early stage, the path to achieving the system objectives was not yet clear for two main reasons: 1) The target users are dyslexics with different requirements than mine and 2) a lack of resources, either technical or psychological, relevant to the difficulties that dyslexics

face in reading tabular-structured data. Three suggested designs emerged that might enhance dyslexics' reading ability. The first solution—the project idea—included hiding the content of webpages except for a row and its header (see image 16). The second solution would hide webpage content except for that of one cell and the labels of the cell's row and column, which would be viewable through the background (see image 17). The user could move from one cell to another along the row by control buttons. The final solution resulted in each row being a different colour (see image 18).

These were the products of a non-dyslexic mind. Thus, the efficiency of the designs depended on evaluating them with dyslexic users. Consequently, finding the right design took some effort beyond the background research. One step included conducting two meetings with dyslexic users. The first one was with Mr. Roger Broadbent, the chair of the MDSHG. The aim of this meeting was to introduce the suggested ideas and discuss possible difficulties. One of the main findings of the meeting was that dyslexics might choose not to use a system, whatever its functionality, if it was difficult to master. A second finding, in terms of suggested designs, was that there is no right answer for dyslexic users; each individual has different needs because they have different difficulties and symptoms. Mr. Broadbent recommended, however, the first and the third solutions.

The second meeting was with Tom Baker, a dyslexic student at the University of Manchester. This meeting had the same objective as the first one. He chose the first option. He also emphasized the provision of multiple colour options because he can read more easily with a green background. The last meeting was with four dyslexic members of the MDSHG. This meeting included discussion of the suggested designs, evaluation of the system interface design and selection of the best way to design the control window. In terms of suggested design, most participants chose the first and third, but suggested some changes. First, they suggested changing the colours of two rows to one with high transparency to avoid the high brightness caused by the white background. For the third, they suggested using use two colours instead of multiple colours.



Figure 17: Visible row and header.



Figure 18: Visible cell and labels.

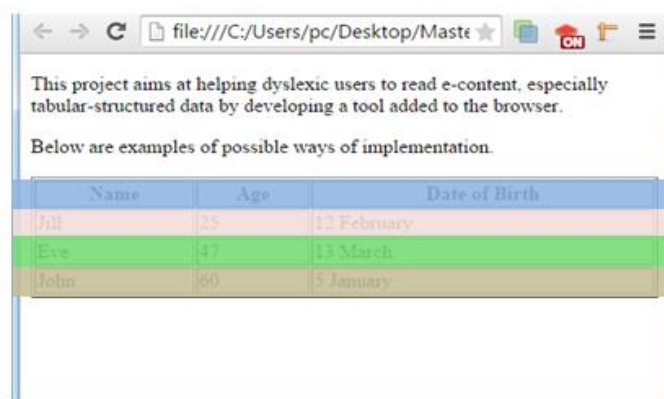


Figure 19: Coloured rows.

B. Finding the Suitable User Interface Design

Designing a system interface for dyslexics is not straightforward. It requires specific considerations when choosing font style, colours and the presentation of the entry elements.

. One group member stopped using advanced mind-mapping software because she kept forgetting how to use it. Thus, three control window designs were presented to the MDSHG (see Figure 20). They recommended the first because of its simplicity

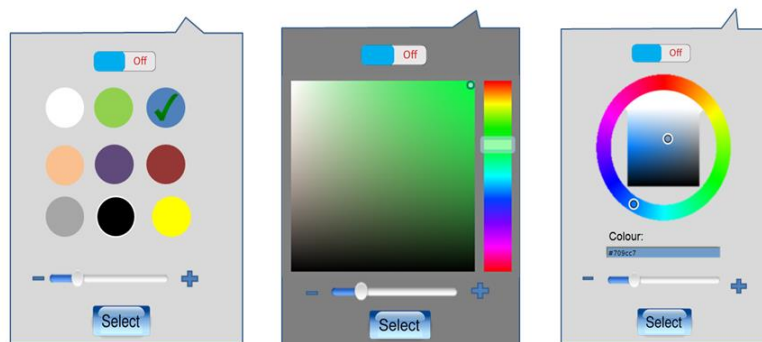


Figure 20: Control window suggestions; the one on the left is the one selected.

To test the functionality of the tool, an initial prototype was created and presented to the MDSHG to see if they could detect a difference with and without the tool and to receive any other recommendations.

The prototype was applied to a webpage containing tabular data (see Figure 21).

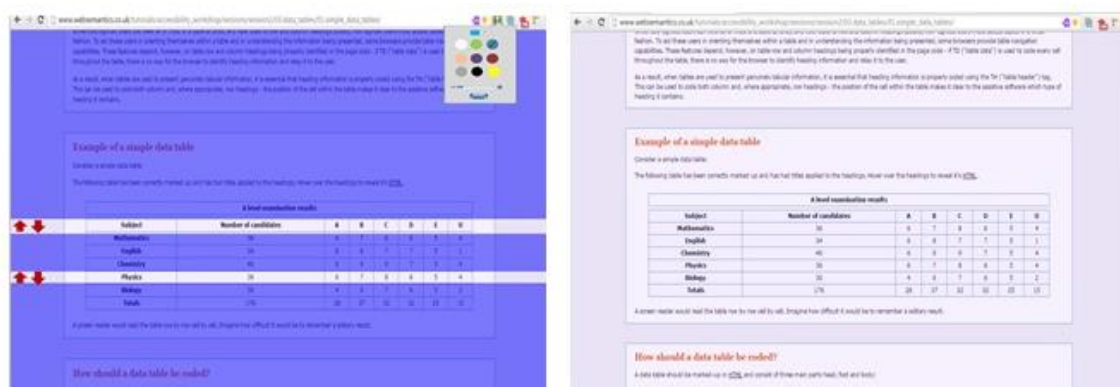


Figure 21: The presentation of a webpage with and without using the tool.

3.1.3.3 Implementation Phase

The implementation phase encompassed evaluation and usability tests using usability software such as Morea, which will be described in Section 5. The cycle of design and evaluation was repeated as often as necessary. For example, after the last evaluation

sessions were held with the target users on the July fourth, some updates were immediately adopted.

3.2 Overview of Building Extensions

According to the official Chrome developers' website [45], extensions are software written using web technologies such as HTML, JavaScript and CSS. These extensions add functionality beyond what is available in Chrome browsers. They install directly, so there is no need to restart the browsers. In addition, installing updated versions is not required; they are updated silently. They work on several platforms such as Mac, Windows and Linux, and Chrome extensions work offline by default. Their development process may seem to be similar to a web development process, but there are differences. These extensions are quite different in terms of structure and logical flow. Below is an overview of the Chrome extension structures and the application program interface API.

3.2.1 The Extension Structure

A Chrome extension is a compressed directory or zip folder with the extension “.crx”. It contains HTML, JavaScript and CSS files. It also has a manifest file that glues HTML to JavaScript files. This manifest file contains information about the extension's structure with JSON-encoded data. It declares the general information such as name, description and version. It also identifies the role of each file in the extension directory. There are two types of files in a Chrome extension. The first one works at the Chrome application level; it includes files such as background and popup files. The second type is injected onto the document object model (DOM) of each webpage; this type includes content script files.

```
"manifest_version": 2,
"name": "Coloured Overlays",
"version": "2",
"description": " This extension helps dyslexic users read e-content, especially tabular-structured data ",
"background_page": "background.html",
"browser_action": {
  "default_icon": "OverlayIcon.png",
  "default_popup": "popup.html",
  "default_title": "Coloured Overlay"
},
"content_scripts": [
  {
    "matches": ["<all_urls>"],
    "css": ["main.css"],
    "js": ["main.js"],
    "run_at": "document_end",
    "all_frames": true
  }
],
"permissions": [
  "<all_urls>"
]
```

Figure 22: The manifest file used in this project.

The manifest file also includes extension components, which provide functionality to these extensions. Below are some components that will be used in this project.

- a. Browser action or page action components: The difference between these components is the appearance in the browser’s URL. The browser action always appears, while the page action appears and disappears, depending on the page’s content. For example, page action is a correct decision if the extension provides features that depend on other features in the page, for example, RSS. These components can contain files such as an icon, a tooltip and a popup.



Figure 23: The difference between browser action and page action.

- b. Content script component: This contains JavaScript and CSS files that are injected into selected pages by the browser. They are executed in parallel with the page’s JavaScript every time webpages are reloaded or opened.
- c. Background page: This contains logic and UI elements. This page is usually an HTML file containing JavaScript and CSS blocks. It exists throughout the extension’s lifetime and allows the extension to communicate with certain web services or APIs.
- d. Utility web files: These include such things as images, Flash movies and JavaScript libraries.

- e. Permission field: This field is added to the manifest file in order to configure the permissions required in the Chrome extension.

3.2.2 The Extension API

The API for Chrome extensions contains a small number of objects and routines. Chrome is the top-level object that is automatically exposed to all extensions. The API is divided into six modules, including extensions, browserActions, pageAction, windows, tabs and bookmarks. Table 1 shows the modules and their functionality.

Table 1: The API modules and their functionality.

The module	Functionality
Chrome.extensions	Sends messages between extension components
Chrome.browserActions	Sets the appearance of the browser action
Chrome.pageAction	Enables and disables page actions
Chrome.bookmarks	Reads from and writes to user's bookmark tree
Chrome.windows	Opens, closes and updates browser windows
Chrome.tabs	Opens, closes and updates browser tabs

3.3 Evaluation plan

Extensive testing was done to ensure the quality of the tool. The unit testing framework called Jasmine was used (see Section 5). Then, the tool was evaluated to check the project's achievements against its aims. Engaging people with dyslexia to evaluate the project is extremely important because they represent the target users; others cannot see the words as they do. Dyslexic users therefore evaluated the tool's functionality and had their reading performance, with and without the tool, measured. This measurement was focussed on reading speed and understanding the tables' content. Questionnaires related to the data measured the users' understanding, as did open interviews. The aim of these interviews is to

understand the difficulties faced and gain additional feedback and recommendations. Therefore, the data collection from the evaluation sessions included a combination of qualitative (interviews) and quantitative (reading speed) data. These evaluations were held in small groups or one-on-one to enable free expression and avoid the use of others' ideas. Six adults evaluated the system. Volunteers included members of the MDSHG [5], which supported this project in the design and evaluation stages. The same number of adult users without dyslexia also participated in the evaluations to determine whether the system helps other users.

3.4 Summary

In this chapter, the method adopted in this project (UCD) was described. The activities of the approach followed were also discussed and linked to different phases (or chapters) of this project. In addition, an overview of the Chrome environment and an evaluation plan was discussed.

4. Design and Implementation

This chapter shows the details of the implementation and design based on the understanding of target users' needs and requirements, as described in chapters 2 and 3.

4.1 System Design

Employing the UCD approach plays a part in ensuring that the tool can be used easily by those with dyslexia. One of the main findings from the related research and meetings conducted with dyslexic users is the importance of the simplicity. Therefore, the basis of the development of this tool was to design the system to be as simple as possible. Simplicity, in this case, means that it should be possible to use the tool without extensive explanation or guides. It also means that the functions are provided with clear and few options options. This helps users to remember the system's functions and options, which consequently will encourage them to use the tool again and again. The power of simplicity is not a new idea. In 1999, Jacob Nielsen found that designing a successful website requires both usability and simplicity [46].

The tool has two main parts. The first is the setting screen in which the user can select the colours and the level of opacity. The user can also move the transparent row by enabling the option in the setting screen. The second part is the floatable screen, which includes some options related to the transparent rows, such as increasing and decreasing the height.

1.2.1 Main Screen Design

The main screen can be seen by clicking the tool icon. It contains a set of colours which are represented as small circles alongside each other. These colours have been chosen based on the participants' favourites and on previous research [2]. The screen also provides an opacity bar, which allows the user to change the transparent level of the floating background. Another of the options in the main screen is the ability to switch the tool on and off. This option is important to allow the user to easily remove the floating background if he/she is not reading a page that contains tabular-structured data. By switching the tool off, all the options in the setting screen will be hidden. The tool status (on or off) is displayed on top of the icon. Finally, the screen allows the user to enable and disable the

movement of the second transparent row by checking the “Start Reading” option. This row moves according to the mouse movement.

The user selects the colour from the colours options. These options will be appear by checking the tool icon. The user can also choose the opacity, and the new value will be displayed as a number next to the opacity bar. The user confirms their choice by clicking the “choose” button.

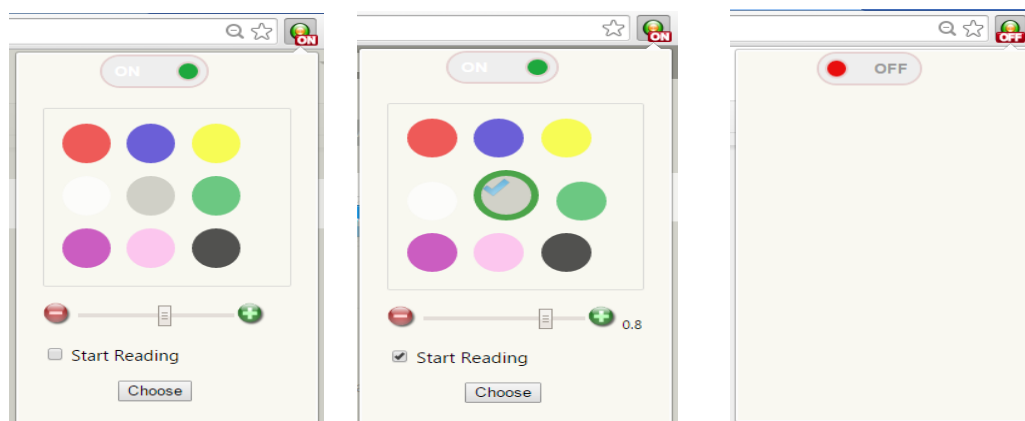


Figure 24: The main/settings screen of the tool. Once a user selects a colour or opacity, it will appear as the image on the middle. If the tool switch is off, it will appear as the left image.

1.2.2 Floatable Screen Design

The second part of the tool is the floatable screen. This screen contains a floatable overlay with two transparent rows. Each of these rows has two options: one for increasing and the other for decreasing the height of the row according to the table that the user is reading. It also has an option in the right-click menu which can be used to change the position of the first transparent row. This option is called “Move the first transparent row”. The second transparent row can be moved by enabling the related option in the main screen (as described earlier). Once the user selects his/her favourite colour and confirms their choice by clicking the “choose” button, the changes will immediately appear in the floating overlay. The overlay here provides the ability to read the text with different colours and level of intensity.

Name	Gender	The Date of Birth	The place of Birth	Job	The Date of Death	No of Children	Mother Name
Tina Josen	Female	20 Sept 2000	UK	Student	11 OCT 2012	0	Amy McDonald
Diann Abram	Female	17 Nov 1967	US	Author	26 May 1989	2	Sarah Newton
William Shakespeare	Male	26 April 1564	England	Playwright, poet, actor	23 April 1616	3	Mary Shakespeare
Lauren Bond	Female	12 March 1590	Canada	Teacher	12 December 1630	3	Ning Lawson
Sara Abel	Femal	11 August 1478	Italy	Sunger	11 July 1540	2	Amy Samuel
Haya Collins	Femal	11 January 1940	Paris	Engineer	12 May 1952	8	Maya William
Samuel Mahmood	Male	12 March 1960	Germany	Fashion Designer	13 August 1978	2	Noor CHADWICK
Tom Carman	Male	11 February 1490	London, UK	Farmer	10 August 1563	3	Nancy Abdoul
Liam Potter	Male	10 October 1578	India	Lawyer	11 August 1620	3	Ellen CAULFIELD
Rata O'Neill	Female	19 MArch 1479	Lebanon	Web Developer	10 December 1512	3	NAdien Noah
Liping Lung	Female	13 Nov 1980	China	Designer	11 Nov 2014	55	Julia James
Jon Charlie	Male	11 MArch 1390	Australia	Dog Trainer	12 March 1449	4	Brooke Howarth
Christan Luke	Male	27 June 1903	US	Doctor	11 October 1982	7	Molly O'Donnell
Jacob Hanson	Male	12 May 1930	UK	Biologist	13 November 1998	3	Adler Joshua
Brian Ethan	Male	12 March 1967	Australia	Teacher	11 July 2012	2	Allan Koreann
Nouf Mohsen	Female	14 March 1907	Saudi Arabia	Childcare Worker	13 November 1979	7	Haya Saeed
Ellie Frost	Male	32 November 1903	Canada	Civil Engineer	4 May 1978	2	Emy Mason
Magi Norman	Femal	11 April 1690	England	Chefs and Head Cooks	14 November 1730	4	Sophie Parry
Billy Carter	Male	13 December 1870	Italy	Architect	13 March 1952	2	Sandra CAUSEY

Figure 25: The floating background with two transparent rows appears on top of a webpage. Both the height of the transparent rows and the position of the first row can also be changed.

4.2 System Implementation

In this section, the details regarding the tool will be explained. These details include the structure of the tool, important code elements and the way the main functions were built. The issues faced during the development are also discussed. Finally, the section concludes by explaining how to configure and use the tool.

4.2.1 Implementation Platforms and Programming Language

As mentioned earlier, the chrome extensions use several technologies, including JavaScript, HTML and CSS. These technologies are popular and reachable, and thus there are many available resources. Moreover, they can be developed by various programs, including even the simplest programs, such as notepad++. However, this extension was developed with a website builder called Adobe Dreamweaver, which is used to enhance the writing, validation and design of websites. It has some features used to facilitate and speed up the process of creating webpages, such as drag and drop, design and view, good highlighting and find and replace, among others.

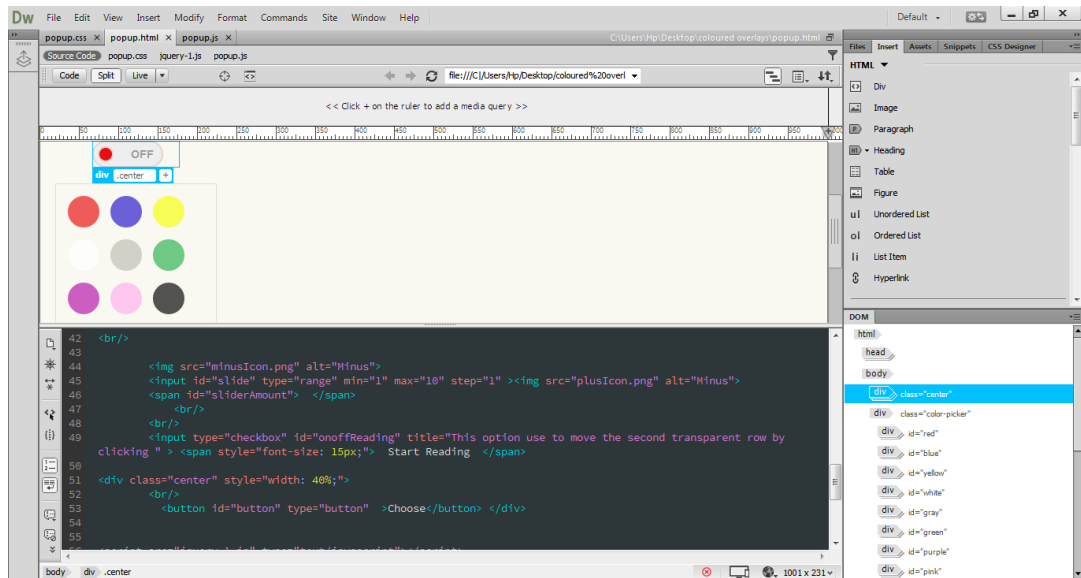


Figure 26: Screenshot of the Dreamweaver platform.

4.2.2 Overall System Architecture and Work Flow

In essence, the tool structure is similar to that of each chrome extension, which was mentioned earlier in Chapter 2. It contains the following three parts: popup, background and content script. All of these parts are controls and are connected through the manifest file. The popup part includes the following three different types of files: HTML, JavaScript and CSS. These files are used to create the main screen. The background part is used as a connector between the main screen (popup part) and the content script (floatable screen). This is because the data cannot pass directly between the main screen and the content script for security reasons. Therefore, the information will be passed to the background page. This will ensure the security of the information since the data are sent through the secure frame to the background before then being sent back to the popup. The background is also used to deal with the local storage, which is used to save the data selected by the users from the main screen, such as colour, opacity, the status of the tool (either on or off) and the status of the reading options. The content script will inform the background once any local storage items have been changed. The background can also access the local storage directly and use the items and/or send these items to the popup part.

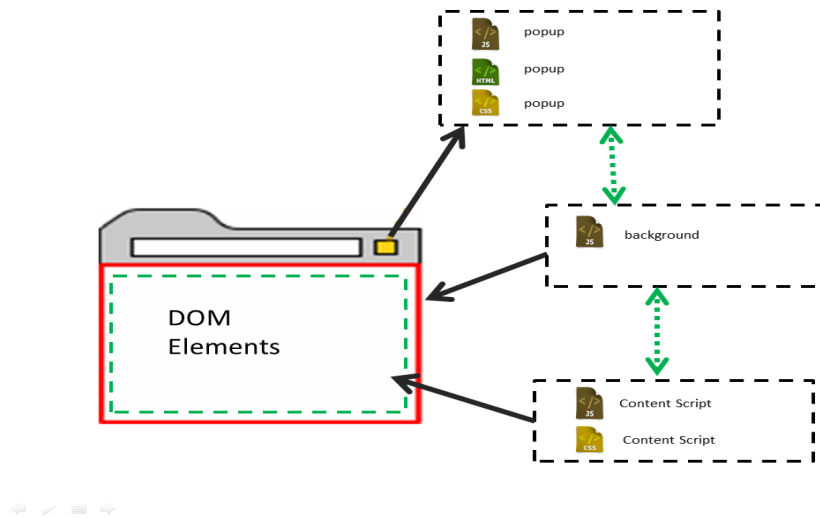


Figure 27: The structure of the tool.

The work flow of this tool’s components begins from the content script, which are injected into each webpage matching the criteria written in the manifest file. The content script will ask the local storage for the values or use the default values. Once the popup page is loaded, it sends a request for data to the content script. The content script processes the request and sends the data through the background. These data are the stored values of colour, opacity and the status of the reading and switching options. Other functions related to the floatable screen are included in the content script, as these functions work when the data in the local storage are changed.

4.2.3 Overview of the Main Functions

A. The Manifest File

Generally speaking, manifest files identify extension resources and the capabilities required to execute the extension. They are the first files read by Chrome when an extension is installed [47]. Each extension has permissions written into the manifest file, and the colour

overlays tool has three types of permissions. The first is called “tabs”. This permission allows the extension to access tab objects using various APIs. The second permission is called “storage”, which allows the tool to use the local storage used to save certain values, as previously mentioned. The third permission is “context menus”, which gives the tool permission to use the context menu [48]. The manifest file also has other fields, such as files, icons used, name, version and description.

B. Choosing a Colour

Choosing an appropriate colour is one of the most important functions in the screen settings. The colour options are built as set of <div> elements, which are divisions in an HTML document. These <div> elements can produce circular shapes that are achieved by using the border-radius property in a CSS file. Each <div> has a different background colour and specifies listeners for click events, which means that when an option is clicked, its icon changes colour and a border is displayed around the clicked colour. These changes are processed in the CSS code, and the new overlay colour is saved in the JavaScript file. However, the new colour is not stored in the local storage, and its current value is not changed until the user clicks a “choose” button.

C. Moving the First and Second Transparent Rows

The way to move the first transparent row is quite similar to the way to move the second transparent row. They are both moved by changing the properties of the foldable screen components, such as height and the padding at the top. However, the main difference is the way these functions are represented. As previously mentioned, moving the first transparent row is done through the right-click menu. There are many reasons why this function is located in the right-click menu. One of them is to allow the click position to be read and another is to move the transparent row by clicking the related option in the menu.

Otherwise, the moving option would have to be located either in the setting screen or in the floatable screen itself. These alternatives are not easy for those with dyslexia because they require setting more options in the setting screen. In addition, such alternative reading positions require users to take more steps.

It is important to know the floatable screen components to understand how the moving transparent rows work. The floatable screen consists of several <div> elements that can divide the screen into two parts. One part is for the first transparent row, which consists of the transparent row itself and two other <div> elements, one in the top and the other in the

bottom. The second part is similar to the first part but refers to the second transparent row. These <div> elements are created dynamically in the content script files using the createElement function in the document object.

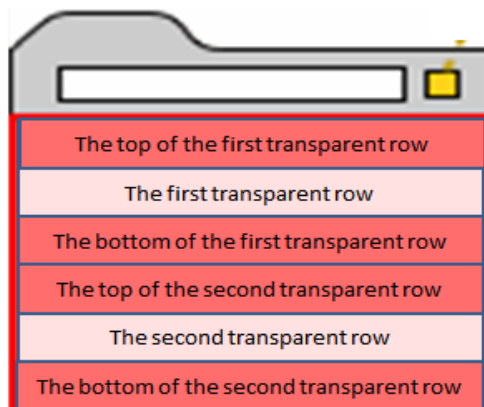


Figure 28: The components of the floatable screen.

The first step in moving a transparent row is to read its new position, which is selected by users. The position is then converted to the Y axis by a percentage to allow for flexible presentation across different platforms, view ports and screen sizes. The percent value is calculated by taking into account whether there is a horizontal scrollbar and dividing the Y position by `window.innerHeight`, which is used to get the window's height. The second step is to decide to which area or components to move a row. The sequence of the transparent rows is also checked. After determining the area and components, the properties can be changed. Mathematical expressions are used to move the row and to make subsequent changes, which depend on the new positions and order of the components. For example, moving the first row up requires that the height of the first component, the top of the first transparent row and the height of the first transparent row be changed. However, the case would be completely different if the second transparent row was above the first one or the first transparent row was moved to another position.

D. Increasing or Decreasing the Height of Transparent Rows

These functions enable users to change the height of transparent rows to fit the height of the tabular-structured data on a webpage. Once the user clicks the minus icon, the height is decreased slightly, and the height is increased by clicking the plus icon. There is no maximum value of the height of the transparent rows, but the increasing process stops if it reaches other transparent rows or the edge of the screen. The minimum value of the height

value is zero, so the user can decrease the height of transparent rows so that they appear on the floatable screen without any transparent parts (see Figure 29).

Name	Gender	The Date of Birth	The place of Birth	Job	The Date of Death	No of Children	Mother Name
Tina Jones	Female	29 Sept 2000	UK	Student	11 OCT 2017	0	Amy McDonald
Diana Adams	Female	17 Nov 1967	UK	Author	28 May 1989	2	Sarah Newton
William Shakespeare	Male	26 April 1564	England	Playwright, poet, actor	23 April 1616	3	Mary Shakespeare
Laura Bond	Female	12 March 1590	Canada	Teacher	12 December 1630	3	Nang Lawson
Sara Abel	Female	11 August 1478	Italy	Singer	11 July 1540	2	Amy Samuel
Hara Collins	Female	11 January 1940	Iran	Engineer	12 May 1952	0	Merv Williams
Samuel Malwood	Male	12 March 1960	Germany	Fashion Designer	13 August 1970	2	Noor CHADWICK
Tom Curran	Male	11 February 1490	London, UK	Father	19 August 1565	3	Soucy Abdoul
Lorna Potter	Male	19 October 1378	India	Lawyer	21 August 1620	3	Elise CAULFIELD
Rita O'Neill	Female	19 March 1479	Lebanon	Web Developer	19 December 1512	3	Nadim Noth
Laping Long	Female	13 Nov 1960	China	Designer	11 Nov 2014	55	Julia James
Jim Charlie	Male	11 March 1390	Australia	Dog Trainer	12 March 1449	4	Bonnie Heworth
Christian Lake	Male	27 June 1903	US	Doctor	11 October 1982	7	Molly O'Donnell
Jacob Hanson	Male	12 May 1930	UK	Biologist	13 November 1990	3	Asher Joshua
Brian Eftan	Male	12 March 1967	Australia	Teacher	11 July 2012	2	Alice Kovacs
Naef Malham	Female	14 March 1907	Saudi Arabia	Childcare Worker	13 November 1978	7	Hara Saad
Elise Frost	Male	32 November 1903	Canada	Civil Engineer	4 May 1970	2	Eary Mason

Figure 29: Minimising the height of transparent rows.

These two functions are similar, except that one function increases the height property and the other decreases it. They are all dynamically defined and processed in the content script files. Basically, they are images assigned to event handlers. There are four events, and each event is processed separately because each deals with a different row (first or second) and function (increasing or decreasing).

E. Making the Screen Floatable

The Z-index is one of the HTML properties used to define the order of HTML elements. The element that has a greater number always precedes those with lower numbers [49]. To calculate the highest Z-index value of dynamic a HTML element, TopZIndex [50] is used. TopZIndex is a JQuery plugin used to calculate the highest CSS Z-index for each element. The value generated by TopZIndex is used to make all screen components floatable.

F. Switching the Tool On and Off

The default method to turn off any Chrome extension is to uncheck its enable box. Doing this, however, requires the user to complete many steps. These steps include clicking the

menu on the browser, selecting “more tools”, choosing “extensions” and, from a list of extensions, unclicking the “enabled” box for the extension that needs to be disabled. This is difficult to remember for those with dyslexia, which makes the tool difficult to use in general. Thus, one of the important functions of this extension is that it easily switches on and off.

Switching this extension on and off is dependent on the hidden HTML element. If the extension is off, the options in the main screen are hidden, and the data are changed in local storage. As a result of this change, the content script is notified, and the floatable screen components are hidden. Text is added to the Google Chrome extension to indicate whether the current setting is on or off. The style of the switch button was generated with animated transitions using Proto.io. [51].

4.2.4 The Configuration Tool

The Chrome Web Store [52] (Figure 30) is a large library of applications and extensions that can be added to the Google Chrome browser. Installing one of the available extensions is a very simple task: choose the extension and click “add to chrome”. After that, the extension is immediately added to the web browser without the need to reopen the browser, at which point users have to double-click the extension icon to show the setting screen.

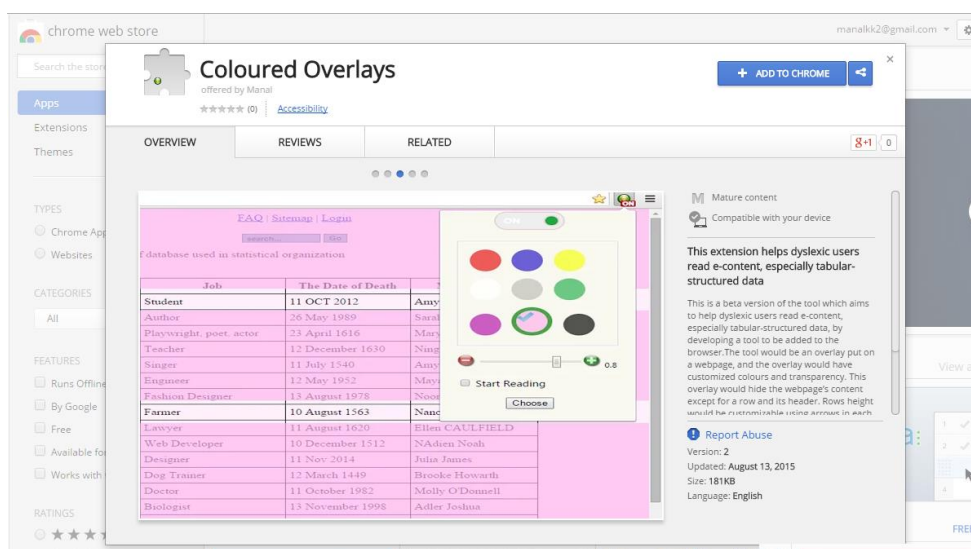


Figure 30: The Chrome Web Store.

4.3 Summary

The development process for Google Chrome extensions is similar to the process for any webpage. The extension consists of HTML, CSS and JavaScript files connected to each other under the control of a manifest file. The debugging process is also similar to that of developing webpages. It is done using built-in tools in the Chrome browser. However, debugging is a boring process because developers have to reload the extensions for any updates, even if they are trivial changes. The main functions provided by the tool are that it allows a user to choose a favourite colour and transparency, move the first and second transparent rows, change the width of the transparent rows and create floatable screens. These functions were developed taking into account the needs of the target users. Thus, simplicity was one of the main rules followed during the development of the tool.

5. System Testing and Evaluation

This section highlights the tests conducted during the development process. The aim of conducting these tests was to ensure that the main functions work correctly and to detect all possible errors in the tool before evaluating it with the users. The evaluation was carried out to ensure the tool is usable and useful for those with dyslexia, specifically, and for all users, in general. The results and the user recommendations are also reported here.

5.1 System Testing

The tool was tested to ensure that the main functions perform as expected, as well as to ensure it is error-free, the time taken by a function to execute is acceptable and the functions are integrated well. To achieve all these objectives, the automated testing framework, called Jasmine [53], was used, along with manual tests. The automated test was used to improve the quality of the test, reduce the need for the manual tests, which are often error-prone, and to run the test frequently and quickly. In addition, automated tests determine how the system reacts to any changes.

Jasmine is a behaviour-driven development framework used to test JavaScript code. It is open source and used to test the units of code. The main features of Jasmine are the independency and the ease of learning. In this tool, the main functions were tested using Jasmine by setting the fixture and comparing the expected results with the actual value that is returned by the function to be tested. These functions are shown in Table 2.

Table 2: Testing of the tool.

Test	Description	Result
Change the first transparent row height	This suite or test unit includes two test functions: one is used to increase the height of the first transparent row and the other to decrease it.	Pass
Change the second transparent row height	This suite tests the functions used to increase and decrease the second transparent row.	Pass
Change the first transparent row position	This unit tests the function used to change the position of the first transparent row. It tests all possible options in terms of the locations of transparent rows.	Pass
Change the second transparent row position	This suite tests the function used to change the position of the second transparent row, with all cases taken into account.	Pass
Test the setting screen	This suite is used to test the main functions shown on the setting screen. These functions include change the overlay colour, change the opacity, turn on function and turn off function.	Pass

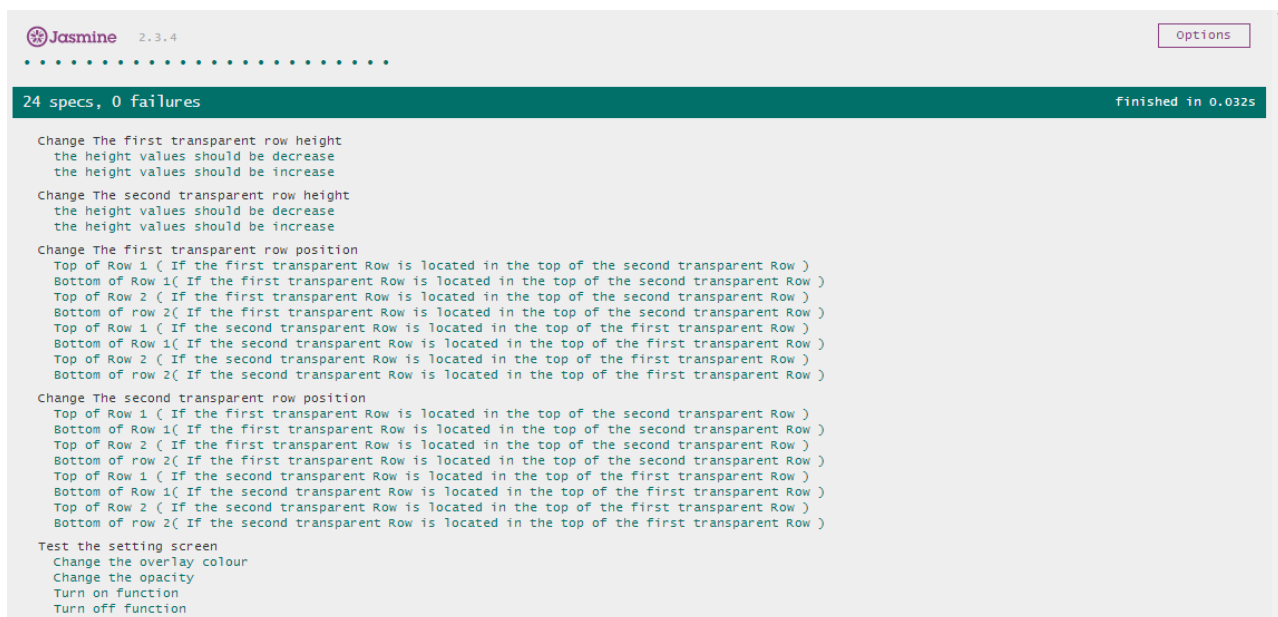


Figure 31: The result of running a test using Jasmine.

In addition, some manual tests were also conducted. These tests include checking the tool functions and checking how these functions work together, such as changing the colours and opacity and moving the transparent rows' positions many times. The performance was also checked manually by writing JavaScript code. The total time taken by all the main functions displayed in Table 2 is less than one second.

5.2 System Evaluation

System evaluation is one of the main aspects of the development process to determine the usefulness of the system, to discover the problems experienced by users working with the tool and to find different ways to improve the tool depending on users' recommendations and feedback. This part discusses the methodology followed to evaluate the tool, the recommendations and the results of the evaluation process.

5.2.1 Experimental Methodology

The methodology adopted in the evaluation process was comprised of semi-structured interviews, the “think aloud” protocol, mouse movement tracking and screen and voice recording. In total, 12 participants were asked before the evaluation session about their technical skills and reading difficulties. Then, they were asked to read tables of data with the screen recorder. After that, they completed a survey about the tool's functionality and usability. The survey used to evaluate the tool's usability is called the System Usability Scale (SUS). It is commonly employed in the usability testing of systems or products. The SUS consists of 10 questions, and each has five points (see Appendix A). At the end, the SUS provides a score from 0 to 100. In the literature, there is a lack of agreement regarding how the score should be presented. According to Bangor et al. (2009) [54], a score equal to or higher than 85 represents a remarkable level of usability and a score under 70 means unacceptable usability. Another common method used to evaluate the SUS score is a “letter grade”, such as A, B, C etc. [55]. Nevertheless, the difference in the score representation, the higher scores usually indicate better usability [56]. The SUS was used because it is simple and provides a quick, low-cost and reliable way to measure the usability of a system or product [57].

During the evaluation sessions, participants were encouraged to speak loudly during task solving. “Think aloud” is a common protocol used to provide a large amount of data about thinking during problem solving or task performance. The collected data can enhance the ability to identify the information concentrated upon during problem solving, and these data facilitate and improve the problem solutions [58]. The types of data collected from the interviews and from the think aloud protocol are qualitative data, while the recorder and SUS provide quantitative data.

5.2.2 Equipment

The evaluation was conducted on an HP laptop running Windows 7 Home Premium 64-bit. The screen and voice recorder used in the evaluation sessions was a Morae recorder. The Morae recorder is a part of the Morae suite [59], which was designed to facilitate and support various types of studies and usability research. For example, the Morae recorder allows designers to configure a study by adding tasks that participants perform or questions that participants are asked. It also provides other features such as Configuration Study information and survey definitions during or at the end of the session. In addition, the Morae Manager was used in the tool evaluation phase to evaluate and review the sessions recorded by the Morae recorder. The Morae Manager allows the users to create graphs from collected data and to build videos and presentations.

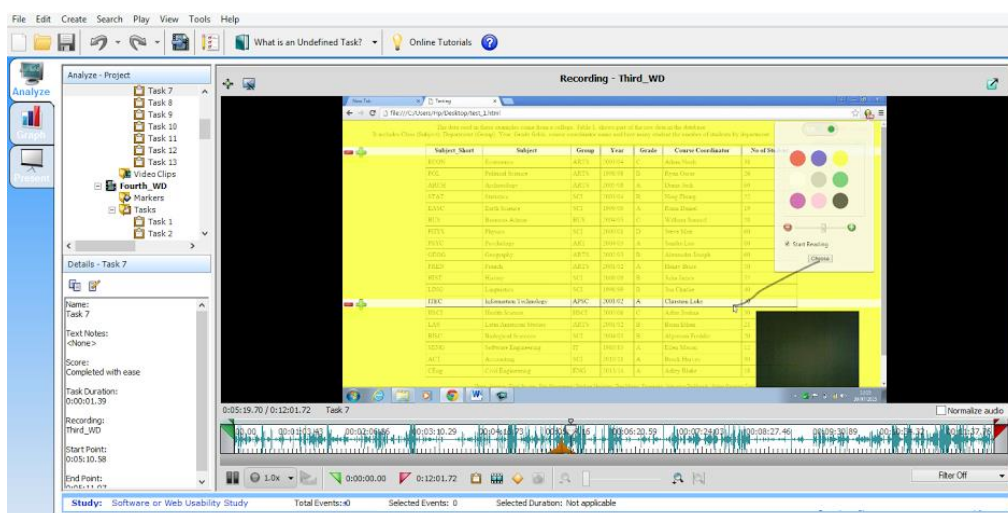


Figure 32: Screenshot of the Morae Manager.

5.2.3 Ethical Approval

The testing and evaluation sessions were conducted with people with dyslexia who are considered people with learning difficulties. These sessions included a software usability evaluation and qualitative and quantitative information gathering. Thus, ethical approval was required. The ethical approval application was submitted via the online system to the central university authentication system of the University of Manchester. The application was approved with approval number CS191.

5.2.4 Participants

The participants were six dyslexic volunteers from the Manchester self-help group. They were adults with considerable computer skills, such as a good use of different input devices. They had also used computers to complete certain tasks, such as web browsing and online banking. These abilities are enough for the participants to use the tool easily. This group of dyslexic participants was comprised of five females and one male.

Another group of volunteers also performed the test. This group was comprised of six adult volunteers who have no history of reading difficulties or dyslexia. This group was also comprised of five females and one male.

5.2.5 Tasks Undertaken

The participants were asked to complete certain tasks written on a piece of paper. These tasks can be divided into two parts. The first aimed to evaluate the usability of the tool by asking the users to perform the most important actions to use the tool appropriately. These actions included choosing a favourite colour and determining a level of transparency. The second part was designed to evaluate the effect of using the tool on the process of reading tabular-structured data. These tasks included finding the answers to certain questions according to the tables given to the users during the evaluation sessions. The participants were asked to use the tool to answer some questions and not to use the tool to answer other questions. This was to determine the difference in the reading performances between using the tool and not using the tool.

The tasks are real tasks written while considering the ability to accomplish them by target users in an acceptable amount of time. The users were asked to complete the important tasks twice to identify whether they were able to remember how to accomplish them in case of failure the first time. All these tasks were written on a sheet given to the users at the beginning of the session (see Appendix A).

5.2.6 Procedure

The evaluation sessions that tested the dyslexic participants were conducted at the Moss Side Leisure Centre, while the sessions that tested the participants without dyslexia were conducted at the Kilburn Building at the University of Manchester. Each session took 15 minutes or more, depending on the information given by the participants and the time taken to complete each task. One participant completed each session. Each participant was interviewed informally before the session started. This interview included two open questions about reading difficulties and computer skills. Then, the tool idea was introduced, and the purpose of the session and the session structure were explained. Approval regarding using the recorder was obtained before introducing the task sheet, while emphasising that the system was being evaluated, not the user, and that these tasks were not a test and any issues indicate design problems.

The task sheet included the reading test, which was comprised of two tables of data in HTML pages. Each table has the same number of columns and rows at 7 and 20, respectively. However, they have different data contexts. The first tables show a part of a database from a college, while the second table is from a statistical organisation. Three questions were asked about each table. The answers had to be chosen from these tables. The time taken for each task and mouse movements were recorded to determine the differences in the reading performances when users were reading with and without using the tool. The participants were encouraged to think aloud while using the tool by asking questions.

As soon as the test was completed, each participant was given the SUS. According to Book (1996), the creator of the SUS, it must be used after the system evaluation and before any discussion and debriefing [57]. Finally, some open questions were posed to the participants. These questions were about the tool and the experience of using the tool.

5.2.7 Results and Interpretation

This section presents the analysis of the participants' performances during the evaluation sessions (qualitative data) and the average time taken to complete the reading test (quantitative data) for the target users and those without dyslexia. A short amount of time taken and a low number of errors are preferred.

5.2.7.1 Sessions with the Target Users

Six dyslexic participants read a table of data using the tool. However, two of them were unable to read the table of data without using the tool. One of those who could not read the table of data without using the tool was not even able to see the screen, while the other could see the screen but could not read any words. It is worth mentioning that the participants have different abilities in reading. Two of them were able to read text without assistance, such as a colour filter or font customiser. Despite the fact that the participants were struggling to access some features of the tool, such as fixing the position of the first transparent row, they all liked the tool's functionalities and features. The features they most liked were the idea of highlighting two rows, the ability to choose your favourite colour and the flexibility to change the height of the rows:

First: "The colours make a difference".

Fifth: "The content is very clear and visible after highlighting".

Sixth: "The page was very bright before turning the tool on".

Second: "The tool was good for focusing".

First: "I like the flexibility of getting the highlighted bar and once you want it to be bigger, it gets bigger".

On the other hand, there were also some critical comments. The majority of these comments were related to design issues. Five out of six were unable to change the first row's position easily the first time. However, two of the five were asked at the end of the session to re-do the tasks, and they were able to remember how to do it. The participants also had various

suggestions for improving the tool. Some of these suggestions are not easy to implement in terms of programming, Google Chrome’s ability or time required. An example of these suggestions is setting the transparent row’s position and size by default. This way, the users choose only the colour and change the height of the transparent rows. However, there were some ideas that can be implemented in the Google Chrome environment, such as adding instructions or guides before running the tool. Another suggestion was given by two participants to provide a feature that enables the users to customise the font, because they found that the font in different sizes (bigger and smaller) was confusing. Difference in font size is common in e-content, especially with tabular data, as the header is often larger than the rest of the text.

Despite all these comments and suggestions, the average time taken to read the tables of data using the tool was 8.4 seconds; without using the tool, it was 13.5 seconds. Table 3 shows the details of the reading test and how many seconds each participant took. It can be seen that the mean of the time taken by each dyslexic user never declined. Figure 33 shows the average time taken to complete each test task (tasks 8–20 using the tool and tasks 11–13 without using the tool).

Table 3: Time in seconds taken per task in the reading test by dyslexic users.

No.	Using the Tool				Without Using the Tool			
	Task 1	Task2	Task3	Averag e	Task1	Task2	Task3	Averag e
1	0:00:10.93	0:00:15.13	0:00:13.11	00:13.1	Could not even try			None
2	0:00:06.23	0:00:08.59	0:00:06.74	00:07.2	0:00:07.39	0:00:15.80	0:00:18.17	00:13.8
3	0:00:07.01	0:00:06.27	0:00:06.46	00:06.6	Could not even try			None
4	0:00:05.23	0:00:05.15	0:00:05.87	00:05.4	0:00:05.12	0:00:07.07	0:00:03.89	00:05.4
5	0:00:08.36	0:00:14.64	0:00:06.22	00:09.7	0:00:31.22	0:00:16.20	0:00:09.77	00:19.1
6	0:00:13.67	0:00:09.19	0:00:02.43	00:08.4	0:00:08.64	0:00:35.19	0:00:03.01	00:15.6

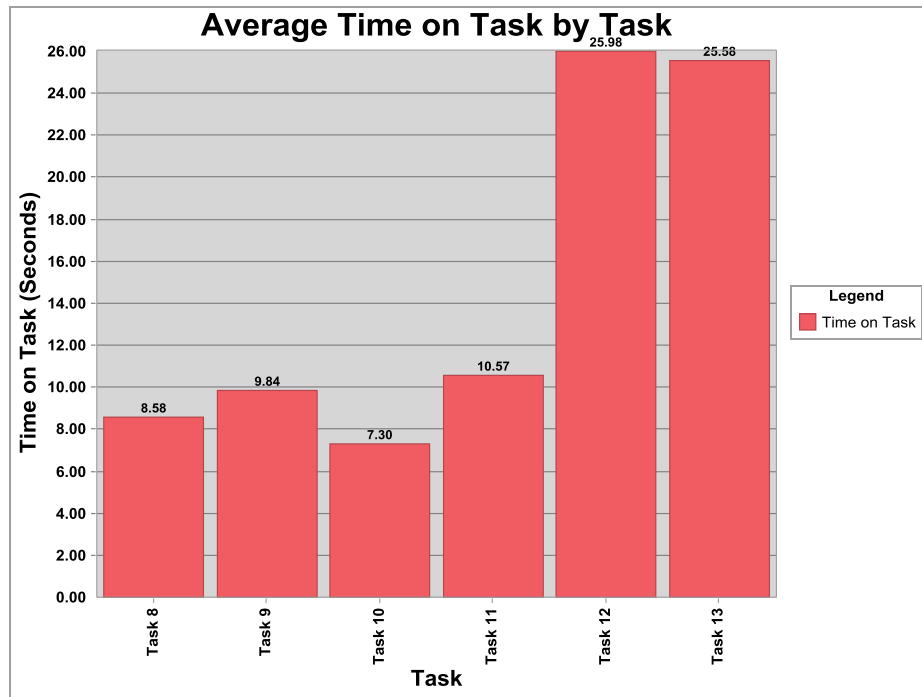


Figure 33: Average time on task by task.

One of the interesting findings was that the dyslexic participants used the mouse less when they were reading the table with the tool (average 377.83) compared to reading without the tool (average 1125.11). Figure 34 shows how Morae captured the mouse movement, and Figure 35 shows the average of mouse movement by tasks. This indicates that they can rely on their visual abilities to read the data with the tool's assistance and that they did not make any mistakes. On the other hand, they used the mouse when they were reading without the tool to help them move through a row and extract the answer from the table. Nevertheless, two out of six made a mistake on one question when they were reading without the tool.

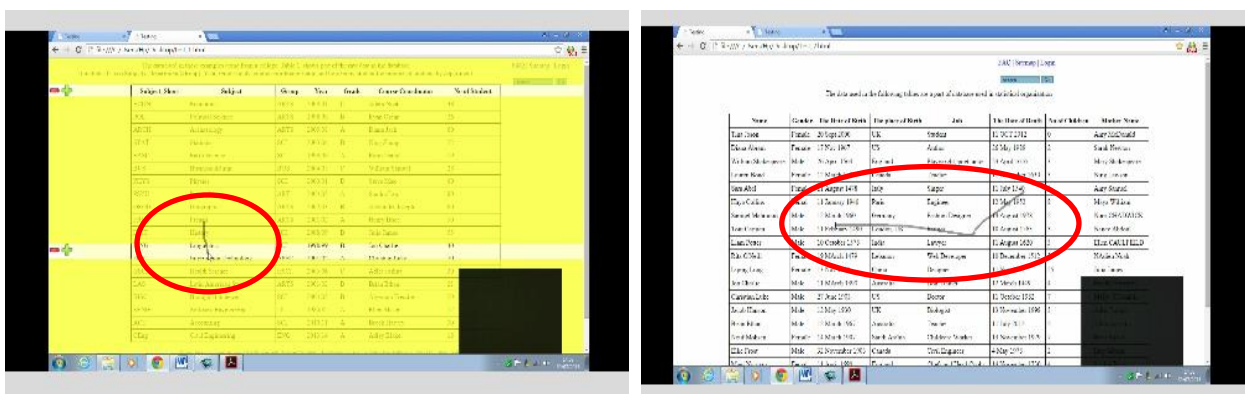


Figure 34: Mouse movement represented in Morae Manager.

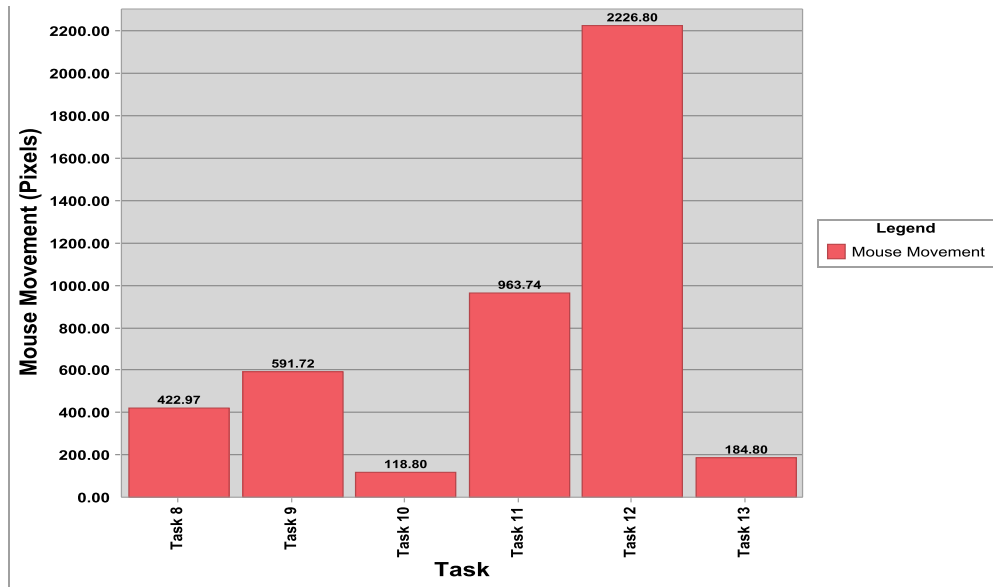


Figure 35: Average of mouse movement by reading task (8–10 without the tool, 11–13 with the tool).

The average SUS score from the dyslexic participants was 51.25, SD 12.62. This score is acceptable for a novel project, as shown in a previous study [54]. The SUS scores for each participant are shown in Figure 36. However, some of the suggestions were implemented and issues fixed before publishing the tool in the Chrome Web Store. An example of such changes is altering the method for moving the second row from clicking to mouse movement. Adding instructions and images to aid in understanding the tool’s functions is another example.

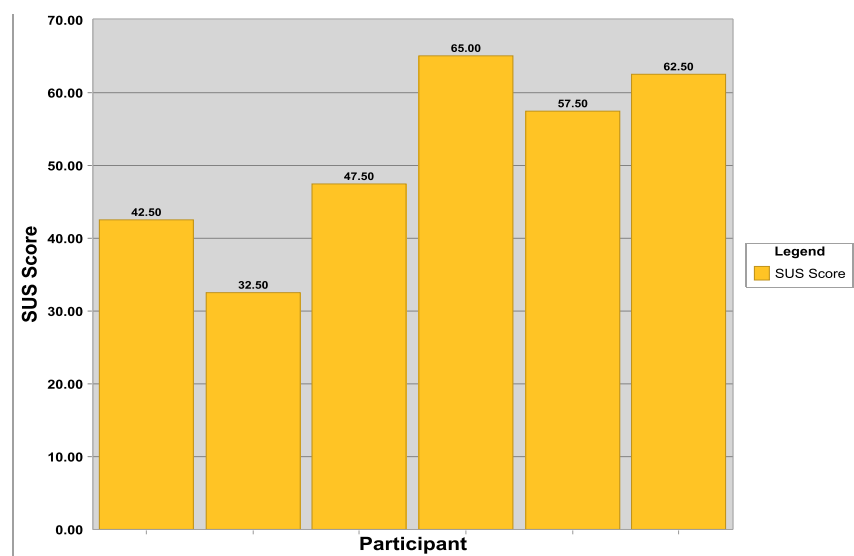


Figure 36: SUS score for each participant with dyslexia.

5.2.7.2 Sessions with Users without Dyslexia

Six non-dyslexic users evaluated the tool in the same manner as those with dyslexia. However, four out of six were computer science students, so they were more likely to have better technical skills than those in the dyslexic group. In addition, they were able to read the table with and without the tool.

Generally, they all liked the functionality provided by the tool and found that the tool made the reading process easier. One participant who works as a lecturer at a university found that the tool could assist her, particularly when she edits student marks. However, one out of six thought that she would not use the tool frequently, because using the tool is an extra task for her. Nevertheless, the average time taken to read tabular-structured data using the tool was 8.9 seconds and without was 12 seconds. Table 4 shows the details of the performances of each participant. It can be seen from the table that the performances of the participants varied, and some of them performed quicker without the tool.

Table 4: Time taken by each task in the reading test by users without dyslexia.

No.	Using the Tool				Without Using the Tool			
	Task 1	Task2	Task3	AVG	Task1	Task2	Task3	AVG
1	0:00:10.08	0:00:09.01	0:00:08.32	00:09.1	0:00:07.23	0:00:08.27	0:00:05.37	00:07.0
2	0:00:14.81	0:00:05.04	0:00:06.01	00:08.6	0:00:20.40	0:00:20.87	0:00:05.92	00:15.7
3	0:00:09.46	0:00:19.55	0:00:06.63	00:11.9	0:00:15.42	0:00:14.55	0:00:09.62	00:13.2
4	0:00:08.21	0:00:04.72	0:00:10.24	00:07.7	0:00:14.43	0:00:09.58	0:00:10.86	00:11.6
5	0:00:09.67	0:00:08.62	0:00:08.61	00:09.0	0:00:11.53	0:00:08.03	0:00:06.77	00:08.8
6	0:00:04.38	0:00:09.85	0:00:07.46	00:07.2	0:00:10.44	0:00:25.25	0:00:10.98	00:15.6

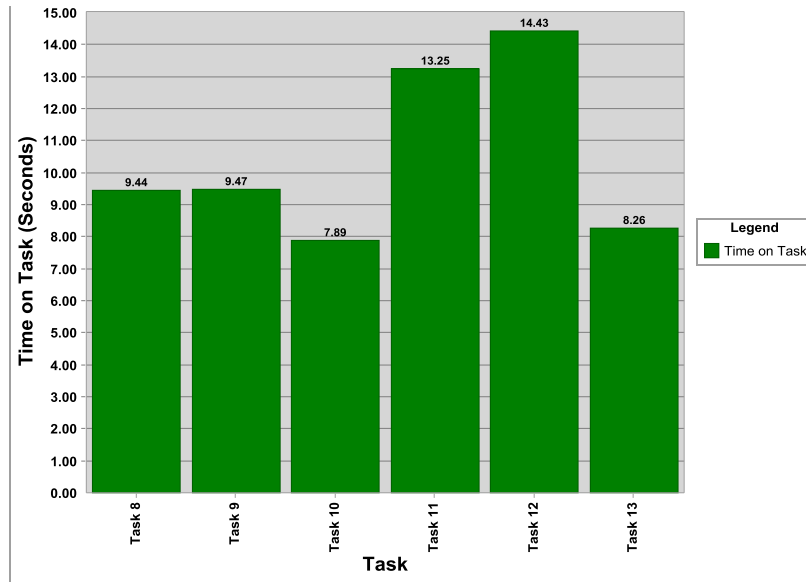


Figure 37: Average time on task by task for non-dyslexics (8–10 using the tool, 11–13 without).

In addition, the non-dyslexic participants used the mouse more when they were reading the tabular data. Figure 38 shows the average mouse movements in each task, while Figure 39 shows the SUS scores achieved by each participant. The average SUS score was 74.17, SD 11.9.

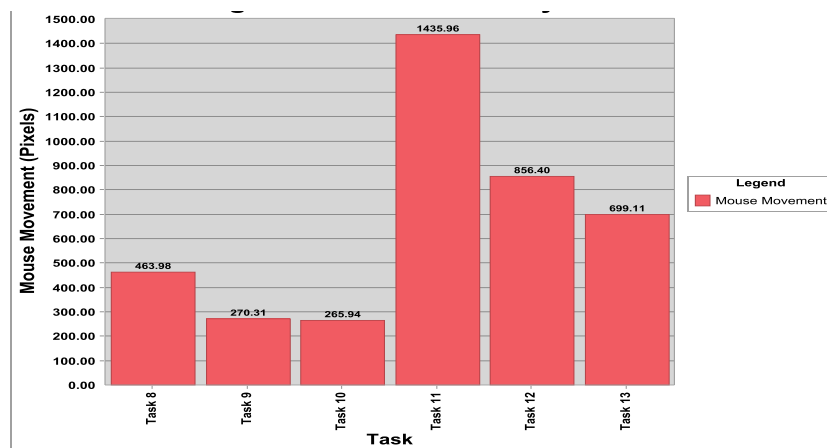


Figure 38: Average mouse movement by task for participants without dyslexia.

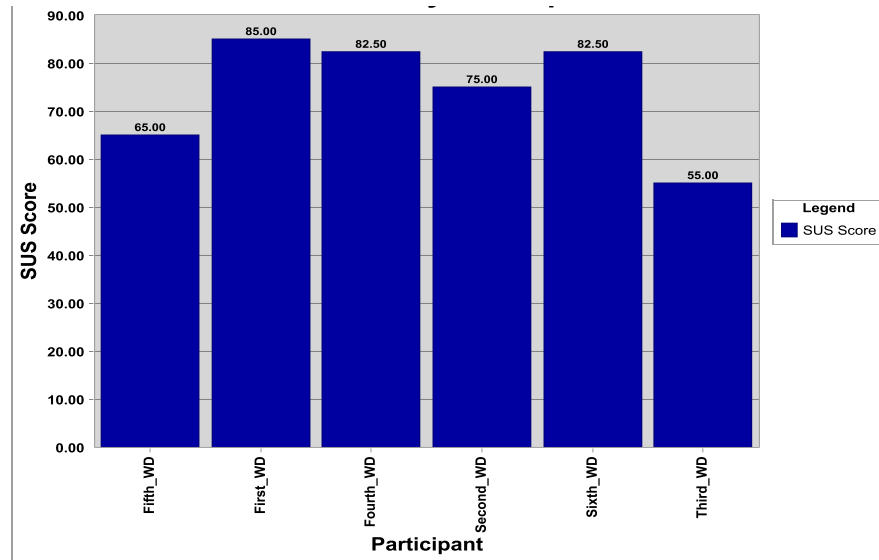


Figure 39: SUS scores for participants without dyslexia.

5.2.7.3 Comparison and Discussion

There was a notable difference between the results for evaluating the tool between the dyslexic and the non-dyslexic group. The time taken to read the tabulated data with the tool was always shorter than without. However, this was not the case with the non-dyslexic group. Moreover, the SUS scores were significantly different between the groups: 74.175 for non-dyslexics, meaning “excellent”, and 51.25 for dyslexics, representing “OK”. The reason might be the differences in the skills and abilities between the two groups. The changes made before evaluating the tool with the non-dyslexic users might also be a reason. Despite these differences, both groups liked the idea of the tool and the assistance that the tool provided. Twelve out of 12 answered yes to the question regarding the ability of the tool to make reading tabular data easier. They enjoyed working with the tool and asked to have a copy of the application. In addition, both groups used the mouse more without the tool. Regardless, the tool required mouse movement to move the second transparent row, which means the tool does affect the reading process. However, the tool can be improved more in terms of functionality by adding new features, such as the ability to change the font size and colour.

In terms of usability, the problem was with the option to move the first transparent row and change the height of the first transparent row. Ten out of 12 struggled to locate the option. Nevertheless, they thought that if they knew how to use the tool, they would not have struggled. The failure to complete task 3, which involved changing the height of the first transparent row, was 0%, while for task 4, which asked the user to move the first row, was

8.33%. Task 5 was similar to task 3, but it asked the user to change the height of the second transparent row, not the first. The time taken to complete this task showed a significant difference. Figure 38 shows the details of the task performance, and Figure 39 shows the time taken for each task by all participants.

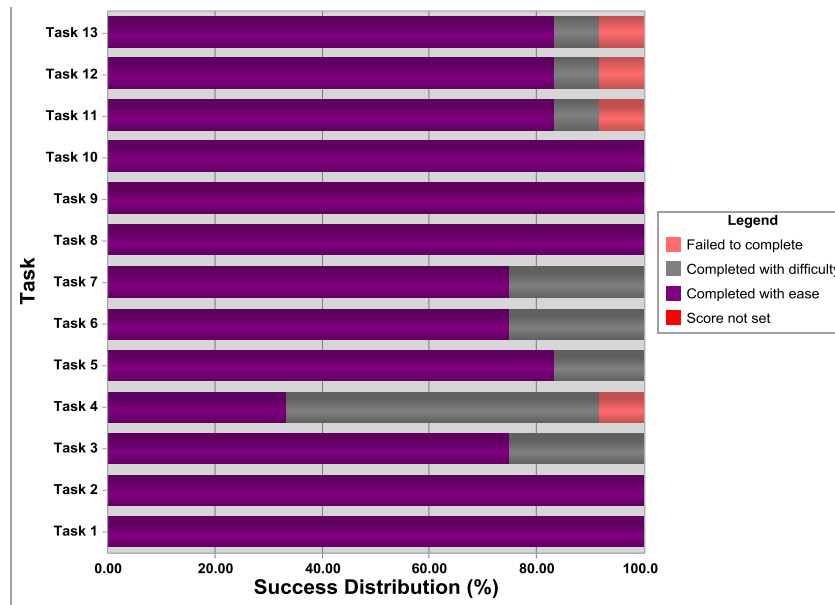


Figure 40: Success distribution by task.

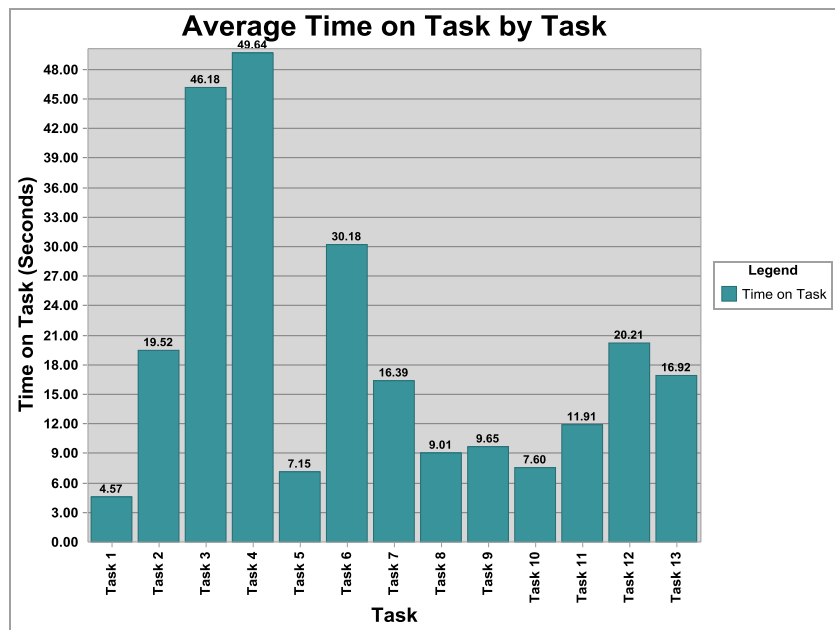


Figure 41: Average time by task.

5.3 Summary

To ensure the tool worked correctly, the main functions were tested using the Jasmine framework. In addition, the tool was evaluated to determine whether the tool achieved the aim of the project, which was to enhance the reading of tabular-structured data for readers with dyslexia. A group of dyslexic adults and another group of non-dyslexic adults took part in the evaluation process. The process of reading tabular data using the tool was different from that without the tool. The tool never decreased the reading performance of those with dyslexia; however, this was not the case for those without dyslexia. According to the user recommendations and feedback, the tool might be improved by adding some functionalities and changing some others. This will be discussed in the next section “Conclusion and Future Work”.

6. Conclusion and Future Work

Dyslexics face significant reading difficulties that cannot be completely resolved, but technologies can reduce the severity of these difficulties. Many assistive technologies are used today, such as text-to-speech systems and coloured-overlay software. Dyslexics with visual stress find these types of software useful because they reduce the apparent movements of letters and words on a page. The existing systems and research, however, focus on reading linear text. Thus, there is a lack of technology to address the ability of dyslexic users to read tabular data. Therefore, the main aim of the project was to create a tool to assist people with reading difficulties to read two-dimensional structured data. To design a tool to be used by dyslexic users who have special requirements and abilities, the UCD approach was adopted in the system's development to ensure its validity. This approach involves target users in the system's development life cycle. The tool is a plug-in (extension) added to the Chrome browser. This tool adds a coloured floating overlay to a webpage, except that two rows have a high level of transparency: one for the table header and the other for the row to be read. The colours and the level of transparency can be customised. The position of the transparent rows can also be changed.

The tool was implemented using HTML, JavaScript and CSS files and tested using the Jasmine framework. The tool was also evaluated by a group of target users who are dyslexic readers and a group of users without any history of reading difficulties or dyslexia. It has been found that there is a slight improvement in the reading process for those with dyslexia in terms of the time taken to extract the data and number of mistakes made. However, in the future, the tool can be improved in terms of functionality and usability.

Dyslexic users who evaluated the tool suggested certain changes because of the difficulties they encountered when they used the tool. These suggestions can be adopted in the future. One of these suggestions involved allowing the user to customise the font of a webpage. This feature is already provided by various extensions, as discussed earlier in the background chapter. Thus, it is possible to add this feature to the tool. However, the user can install a tool providing this feature and use it with the developed tool.

Another suggestion was that the size and position of the transparent rows be provided automatically at the beginning. If the table on a webpage was created by an HTML tag that will be implemented perfectly, where the first transparent row will be the same size as the header <th> and the second transparent row will be the same size as a row <tr>. If the table is an image, the user will set the size and position manually. Regardless, the change to the interface design might enhance the usability of the developed tool. Depending on the behaviours of the users when they were using the tool, there are two design suggestions. These designs must be evaluated by the target users before implementation.



Figure 42: Two interface designs suggested after tracking the users' behaviours while using the developed tool.

Although the tool is novel, the study shows that the tool has a positive effect on the process of reading a table of data for those with reading difficulties. The idea of the project might be a stepping stone for more systems in the future such as applying the tool's functions to spreadsheet applications, including Microsoft Excel, by developing "add-ons" using C# or C++ [60]. Adding an assistive tool to the Excel file would not only help dyslexic readers but may also help dyscalculia users who have difficulties with numbers. People with dyscalculia do not have a sense of numbers, which causes many problems when doing math. In addition, in some cases, they do not see the numbers correctly. Compared with another types of learning difficulties, dyscalculia has generated only little interest and research [61]. In addition, the tool might also assist those who have to work with numbers carefully; accountants, for example, may find the tool useful.

Various ideas might be implemented to augment the tool, as well as more ideas to create new assistive applications in the future. However, implementing all of these ideas requires a strong passion for invention, no matter how simple they are; the issue is with how these

ideas can assist users who have special requirements to complete their tasks without struggling. Beyond this passion, finding volunteers who can turn rough ideas into strong and real software is extremely important. The dyslexic self-help group played a significant role during the project life cycle. Therefore, responsible institutions must be involved in supporting simple ideas and solving minor issues by finding suitable volunteers. While great achievements start small, this study and previous studies or applications have shown that small ideas might lead to solutions for individuals with dyslexia and, hopefully, this will encourage more developers to work in this domain.

7. References

- [1] C. N. Chu and Y.-M. Yeh, "Adaptive reading: a design of reading browser with dynamic alternative text multimedia dictionaries for the text reading difficulty readers," presented at the *Proceedings of the 12th International Conference on Computers Helping People With Special Needs: Part I*, Vienna, Austria, 2010.
- [2] L. Rello, G. Kanvinde, and R. Baeza-Yates, "Layout guidelines for web text and a web service to improve accessibility for dyslexics," in *Proceedings of the International Cross-Disciplinary Conference on Web Accessibility*, 2012, p. 36.
- [3] J. E. McCarthy and S. J. Swierenga, "What we know about dyslexia and web accessibility: a research review," *Universal Access in the Information Society*, vol. 9, pp. 147-152, 2010.
- [4] S. Kurniawan and G. Conroy, "Comparing comprehension speed and accuracy of online information in students with and without dyslexia. Advances in Universal Web Design and Evaluation: Research, Trends and Opportunities," in *Trends and Opportunities*, Idea Group Publishing, Hershey PA, pp. 257-270, 2006.
- [5] Manchester Dyslexia Self Help Group Official website. (9th March 2015). *Home Page*. Available: <http://manchesterdyslexicselfhelpgroup.weebly.com/>
- [6] G. Reid. (2007, 5th April). *Dyslexia: Assessment, teaching and learning: implications for practice*. Available: <http://www.ssc.education.ed.ac.uk/courses/deaf/dmay07b.html>
- [7] International Dyslexia Association. (9th April 2015). *Definition of dyslexia*. Available: <http://eida.org/definition-of-dyslexia/>
- [8] R. Davis, *The Gift of Dyslexia: Why Some of the Brightest People Can't Read and How They Can Learn*, Souvenir Press, 2010.
- [9] The NHS official Website. (7th April 2015). *Causes of dyslexia*. Available: <http://www.nhs.uk/Conditions/Dyslexia/Pages/Causes.aspx>
- [10] J. Bradford, "What causes dyslexia," *Dyslexia Online Magazine*, 2003.
- [11] The NHS Official Website. (7th April 2015). *Symptoms of dyslexia*. Available: <http://www.nhs.uk/Conditions/Dyslexia/Pages/Causes.aspx>
- [12] MedicineNet. (21st March 2015). *What type of treatment is available for dyslexia?* Available: <http://www.medicinenet.com/dyslexia/page5.htm>
- [13] N. Choices. (21st March 2015). *Treating dyslexia*. Available: <http://www.nhs.uk/Conditions/Dyslexia/Pages/Treatment.aspx>
- [14] S. Nourbakhsh, M. Mansor, M. Baba, and Z. Madon, "The effects of multisensory method and cognitive skills training on perceptual performance and reading ability among dyslexic students in Tehran-Iran," *International Journal of Psychological Studies*, vol. 5, p. 92, 2013.
- [15] M. J. Snowling and C. Hulme, "Annual Research Review: The nature and classification of reading disorders—a commentary on proposals for DSM-5," *Journal of Child Psychology and Psychiatry*, vol. 53, pp. 593-607, 2012.
- [16] M. GroGan and M. G. Daigaku, "Pronunciation activities in extensive reading classes," *Extensive Reading World Congress Proceeding*, pp. 172-175, 2012.
- [17] J. Ohene-Djan and R. Begum, "Multisensory games for dyslexic children," in *Workshop on Advanced Learning Technologies for Disabled and Non-Disabled People (WALTD)*, 2008.
- [18] S. Z. Ahmad, N. N. A. A. N. Ludin, H. M. Ekhsan, A. Rosmani, and M. Ismail, "Bijak Membaca—Applying Phonic Reading Technique and Multisensory Approach with interactive multimedia for dyslexia children," in *Humanities, Science and Engineering (CHUSER), 2012 IEEE Colloquium on*, 2012, pp. 554-559.
- [19] P. Tzouveli, A. Schmidt, M. Schneider, A. Symvonis, and S. Kollias, "Adaptive reading assistance for the inclusion of students with dyslexia: the AGENT-DYSL approach," in *Advanced Learning Technologies, 2008. ICALT'08. Eighth IEEE International Conference on*, 2008, pp. 167-171.
- [20] K. E. Forgrave, "Assistive technology: Empowering students with learning disabilities," *The Clearing House*, vol. 75, pp. 122-126, 2002.

- [21] J. Elkind, M. S. Black, and C. Murray, "Computer-based compensation of adult reading disabilities," *Annals of Dyslexia*, vol. 46, pp. 159-186, 1996.
- [22] J. K. Torgesen and T. A. Barker, "Computers as aids in the prevention and remediation of reading disabilities," *Learning Disability Quarterly*, vol. 18, pp. 76-87, 1995.
- [23] C. Goldfus and E. Gotesman, "The impact of assistive technologies on the reading outcomes of college students with dyslexia," *Educational Technology*, vol. 50, pp. 21-25, 2010.
- [24] H.-Y. Chiang and C.-H. Liu, "Evaluation of the benefits of assistive reading software: Perceptions of high school students with learning disabilities," *Assistive Technology*, vol. 23, pp. 199-204, 2011.
- [25] Buchanan Optometrists. (25th March 2015). *Coloured Overlay Assessment and Meares-Irlen Syndrome*. Available: http://www.optometrists.co.uk/examinations/Coloured_Overlay_Assessment_and_Meares-Irlen_Syndrome/
- [26] A. J. Wilkins, *Reading Through Colour: How Coloured Filters Can Reduce Reading Difficulty, Eye Strain, And Headaches*, John Wiley & Sons, 2003.
- [27] A. Wilkins, E. Lewis, F. Smith, E. Rowland, and W. Tweedie, "Coloured overlays and their benefit for reading," *Journal of Research in Reading*, vol. 24, pp. 41-64, 2001.
- [28] L. Phipps, A. Sutherland, and J. Seale, *Access All Areas: disability, technology and learning*, TechDis with the Association for Learning Technology, 2002.
- [29] Rawstream. (25th March 2015). Available: <http://blog.rawstream.com/chromebook-support-for-irlen-syndrome/>
- [30] ReadEZ official website. (25th March 2015). *ReadEZ Virtual Overlay Software*. Available: <http://www.readez.co.uk/virtual-overlay-software/>
- [31] K. Elkind and J. Elkind, "Text-to-speech software for reading," *Perspectives*, vol. 33, pp. 11-16, 2007.
- [32] Claro Software. (17th August 2015). *Home Page*. Available: <https://www.clarosoftware.com/>
- [33] TextHelp. (27th March 2015). Available: <http://rw.texthelp.com/drive/Support/Start>
- [34] Freedom Scientific. (27th March 2015). Available: <http://www2.freedomscientific.com/lsg/products/wynn.asp>
- [35] University of Michiga. (25th March 2015). *WYNN Software*. Available: <http://www.itcs.umich.edu/atcs/wynn.php>
- [36] Scanning Pen Shop. (27th March 2015). Available: <http://www.scanningpenshop.com/en/catalog/product/view/id/101>
- [37] L. Rello and R. Baeza-Yates, "Good fonts for dyslexia," in *Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility*, 2013, p. 14.
- [38] OpenDyslexic Font Official website. (27th March 2015). *About page*. Available: <http://opendyslexic.org/about/>
- [39] T. Katzir, S. Hershko, and V. Halamish, "The effect of font size on reading comprehension on second and fifth grade children: bigger is not always better," *PLoS one*, vol. 8, p. e74061, 2013.
- [40] E. Frank Lopresti, A. Mihailidis, and N. Kirsch, "Assistive technology for cognitive rehabilitation: State of the art," *Neuropsychological Rehabilitation*, vol. 14, pp. 5-39, 2004.
- [41] P. Gregor, A. Dickinson, A. Macaffer, and P. Andreasen, "SeeWord—a personal word processing environment for dyslexic computer users," *British Journal of Educational Technology*, vol. 34, pp. 341-355, 2003.
- [42] British Dyslexia Association. (3rd April 2015). *Dyslexia style guide*. Available: http://www.bdadyslexia.org.uk/common/ckeditor/filemanager/userfiles/About_Us/policies/Dyslexia_Style_Guide.pdf
- [43] The World Wide Web Consortium. (3rd April 2015). *Tables*. Available: <http://www.w3.org/TR/html401/struct/tables.html>
- [44] The International Organization for Standardization. (24th April 2015). *ISO 13407:1999*. Available: http://www.iso.org/iso/catalogue_detail.htm?csnumber=21197

- [45] Chrome Developers. (28th April 2015). *Getting started: Building a Chrome extension*. Available: <https://developer.chrome.com/extensions/getstarted>
- [46] J. Nielsen, *Designing Web Usability: The Practice of Simplicity*, New Riders Publishing, 1999.
- [47] A. Guha, M. Fredrikson, B. Livshits, and N. Swamy, "Verified security for browser extensions," in *Security and Privacy (SP), 2011 IEEE Symposium on*, 2011, pp. 115-130.
- [48] C. Developers. (28th June 2015). *Declare permissions*. Available: https://developer.chrome.com/extensions/declare_permissions
- [49] W3C Schools. (3rd July 2015). *CSS z-index Property*. Available: http://www.w3schools.com/cssref/pr_pos_z-index.asp.
- [50] TopZIndex. (29th June 2015). *TopZIndex plugin for jQuery (V 1.2 ed.)*. Available: <https://code.google.com/p/topzindex/downloads/list>
- [51] Proto.io. (30th June 2015). *On/off flipswitch*. Available: <https://proto.io/freebies/onoff/>
- [52] Google Chrome Web Store. (12th July 2015). *Extensions*. Available: <https://chrome.google.com/webstore/category/extensions>
- [53] Jasmine. (2nd July 2015). *The home page of Jasmine framework*. Available: <http://jasmine.github.io/>
- [54] A. Bangor, P. Kortum, and J. Miller, "Determining what individual SUS scores mean: Adding an adjective rating scale," *Journal of Usability Studies*, vol. 4, pp. 114-123, 2009.
- [55] S. C. Peres, T. Pham, and R. Phillips, "Validation of the System Usability Scale (SUS) – SUS in the Wild," in *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 2013, pp. 192-196.
- [56] A. Bangor, P. T. Kortum, and J. T. Miller, "An empirical evaluation of the system usability scale," *Intl. Journal of Human-Computer Interaction*, vol. 24, pp. 574-594, 2008.
- [57] J. Brooke, "SUS-A quick and dirty usability scale," *Usability evaluation in industry*, vol. 189, pp. 4-7, 1996.
- [58] M. E. Fonteyn, B. Kuipers, and S. J. Grobe, "A description of think aloud method and protocol analysis," *Qualitative Health Research*, vol. 3, pp. 430-441, 1993.
- [59] TEchSmith. (20th July 2015). *Morae*. Available: <https://www.techsmith.com/morae.html>
- [60] Microsoft Developers Network. (9th August 2015). *Tips and tricks: Building Microsoft Office add-ins with Visual C# .NET and Visual Basic .NET*. Available: [https://msdn.microsoft.com/en-us/library/aa289518\(v=vs.71\).aspx](https://msdn.microsoft.com/en-us/library/aa289518(v=vs.71).aspx)
- [61] R. C. Kadosh and V. Walsh, "Dyscalculia," *Current Biology*, vol. 17, pp. R946-R947, 2007.

Appendix A

Appendix A shows the task sheets which were given to the users during the evaluation sessions.

Task Sheet -1-

1. Switch the tool ON.
 2. Choose your favourite colour, and adjust the opacity to your preferred level.
 3. Change the height of the first transparent row (the first highlighted row) so that it fits the height of the header row.
 4. Change the position of the first row.
 5. Change the height of the second row.
 6. Check the “Start reading” option.
 7. Move the second transparent row through the table and place it in the row that you want to read.
 8. Please find the answers to these three questions:
 - a. How many students take Business Admin as a subject?
 - b. What is the grade for the subject French?
 - c. What is the name of the coordinator of the Information Technology course?
- 3 and 4 are interchangeable

Task Sheet -2-

Please locate the following in the table:

- a. The name of Diana Abram's mother
- b. The date Sara Abel died
- c. Tom Carman's place of birth

After the session:

1. For each of the following statements, mark one box that best describes your reactions to the tool today.

Statements	Strongly Disagree [1]	[2]	[3]	[4]	Strongly Agree [5]
I think that I would like to use this website frequently.					
I found this website unnecessarily complex.					
I thought this website was easy to use					
I think that I would need assistance to be able to use this website.					
I found the various functions in this website to be well integrated.					
I thought there was too much inconsistency in this website.					
I would imagine that most people would learn to use this website very quickly.					
I found this website very cumbersome/awkward to use.					
I felt very confident using this website.					
I needed to learn a lot of things before I could get going with this website.					

2. Answer the following questions:

- A. Does the extension make it easier to read the tabular-structured data?
- B. How easy did you find the tasks?
- C. What did you especially like about the program?
- D. Is there anything you would change about the tool?

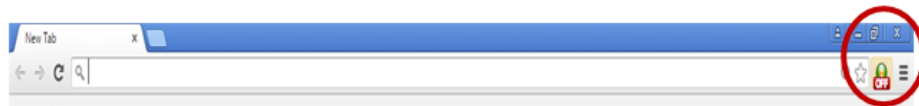
Appendix B

This appendix illustrates the user guide for the tool.

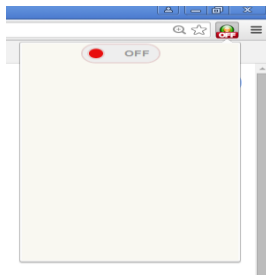
A. Install the Google Chrome extension

To install the Google Chrome extension:

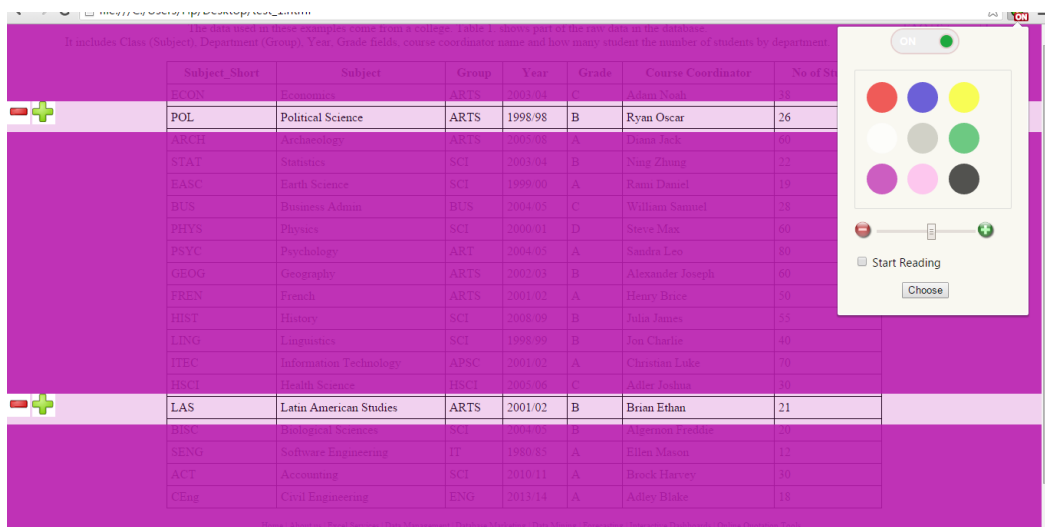
1. Go to the extension page at the Google Chrome web store, which can be found at <https://chrome.google.com/webstore/detail/colouredoverlays/dlchmnhpdepeicnnhpeofcdl/jakcgnjl>
2. Click **Add to Chrome**.
3. Click **Add** to install the extension.
4. The tool will be installed automatically, and the icon will appear to the right of the URL bar.



5. Click on the tool icon to display the main window.



6. Switch the tool on by clicking the switch button. The setting options will be displayed.
7. Select your favourite colour and the required level of transparency, and press the **Choose** button.



- Change the first transparent row's height by clicking the plus and minus icons shown on the left side of the row.
- Change the position of the first transparent row by right-clicking the position to which the row should be moved and selecting **Move The First Transparent Row Here**.

Subject_Short	Subject	Group	Year	Grade	Course Coordinator	No of Students
ECON	Economics	ARTS	2003-04	C	Adam Noah	38
POL	Political Science	ARTS	1998-98	B	Ryan Oscar	26
ARCH	Archaeology	ARTS	2005-08	A	Dana Jack	60
STAT	Statistics	SCI	2003-04	B	Ning Zhong	22
EASC	Earth Science	SCI	1999-00	A	Rami Daniel	19
BUS	Business Admin	BUS	2004-05	C	William Samuel	28
PHYS	Physics	SCI	2000-01	D	Steve Max	60
PSYC	Psychology	ART	2004-05	A	Sandra Leo	80
GEOG	Geography	ARTS	2002-03	B	Alexander Joseph	60
FREN	French	ARTS	2001-02	A	Henry Brice	50
HIST	History	SCI	2008-09	B	Julia James	55
LING	Linguistics	SCI	1998-99	B	Jon Charlie	40
ITEC	Information Technology	APSC	2001-02	A	Christian Luke	30
HSCI	Health Science	HSCI	2005-06	C	Adler Joshua	30
LAS	Latin American Studies	ARTS	2001-02	B	Brian Ethan	21
BISC	Biological Sciences	SCI	2004-05	B	Algernon Freddie	20
SENG	Software Engineering	IT	1980-85	A	Ellen Mason	12
ACT	Accounting	SCI	2010-11	A	Brock Harvey	30
CEng	Civil Engineering	ENG	2013-14	A	Adley Blake	18

- Change the height of the second transparent row in the same way as the first row: by using the plus and minus icons to the left of the row.
- Check the **Start Reading** option. This option will move the second transparent row into place.

Subject_Short	Subject	Group	Year	Grade	Course Coordinator	No of Students
ECON	Economics	ARTS	2003-04	C	Adam Noah	38
POL	Political Science	ARTS	1998-98	B	Ryan Oscar	26
ARCH	Archaeology	ARTS	2005-08	A	Dana Jack	60
STAT	Statistics	SCI	2003-04	B	Ning Zhong	22
EASC	Earth Science	SCI	1999-00	A	Rami Daniel	19
BUS	Business Admin	BUS	2004-05	C	William Samuel	28
PHYS	Physics	SCI	2000-01	D	Steve Max	60
PSYC	Psychology	ART	2004-05	A	Sandra Leo	80
GEOG	Geography	ARTS	2002-03	B	Alexander Joseph	60
FREN	French	ARTS	2001-02	A	Henry Brice	50
HIST	History	SCI	2008-09	B	Julia James	55
LING	Linguistics	SCI	1998-99	B	Jon Charlie	40
ITEC	Information Technology	APSC	2001-02	A	Christian Luke	30
HSCI	Health Science	HSCI	2005-06	C	Adler Joshua	30
LAS	Latin American Studies	ARTS	2001-02	B	Brian Ethan	21
BISC	Biological Sciences	SCI	2004-05	B	Algernon Freddie	20
SENG	Software Engineering	IT	1980-85	A	Ellen Mason	12
ACT	Accounting	SCI	2010-11	A	Brock Harvey	30
CEng	Civil Engineering	ENG	2013-14	A	Adley Blake	18

- To hide the floating background, switch the tool **Off**.



The data used in these examples come from a college. Table 1. shows part of the in the database.

It includes Class (Subject), Department (Group), Year, Grade fields, course code name and how many student the number of students by department.

Subject_Short	Subject	Group	Year	Grade	Cc
ECON	Economics	ARTS	2003/04	C	Ac
POL	Political Science	ARTS	1998/98	B	Ry
ARCH	Archaeology	ARTS	2005/08	A	Di
STAT	Statistics	SCI	2003/04	B	Ni
EASC	Earth Science	SCI	1999/00	A	Ra
BUS	Business Admin	BUS	2004/05	C	W Sa

B. Uninstall or disable the Google Chrome extension

To delete or disable the Google Chrome extension:

1. Click **Menu** , which is located in the upper left-hand corner of your browser.
2. Select **More Tools > Extensions**.
3. Go to the extension that you want to remove and click **Remove from Chrome** .
4. A confirmation message will appear, requesting your approval. Click **Remove** to remove the extension, or uncheck the **Enable** box **Enable** to disable the icon.

Appendix C

This appendix details the evaluation sessions for each dyslexic and non-dyslexic participant.

1. Users with dyslexia

Participant 1: This participant liked the colours and the idea of highlighting the rows; however, she thought that having to adjust the size and positions was cumbersome. She suggested improving flexibility by setting the size and positions automatically and giving users the option to increase the size if they want. On the whole, she found the tasks easy and would like to use the tool again.

Participant 2: This participant had good technical skills. She liked the idea of highlighting and focusing; however, she suggested adding font options because she felt that changing font colours was sometimes not enough, especially in her case. She was able to answer the questions without using the tools although she took more time to do this than reading with the tools. She also used the mouse more without the tools.

Participant 3: This participant had a strong visual stress. She liked the idea of changing the colours and levels of transparency. She also liked the focusing function and found that extremely helpful. She did not use the technology frequently. Highlighting the header was sufficient for her while moving the second row was an extra task. She suggested adding a feature to help users make the text a uniform size. The different font sizes (bigger and smaller) were confusing for her. I asked her to answer the question with the overlay colour without the transparent parts, and she was able to do that but required more time on average (Task 1: 0:00:07.71, Task 2: 0:00:26.67, Task 3: 0:00:13.15).

Participant 4: This participant had good technical and reading skills. She was able to read the table with and without using the tool in a very short period of time. When using the tool, she did not move the second row in all situations. She liked the idea of controlling the table and suggested adding some instructions, because she felt that users would not find the tool very easy to use at first.

Participant 5: This participant had good reading skills. She was able to read the table in black and white; however, she took more time doing this. She was able to use the tool easily and did not suggest any changes to the tool. She liked the highlighting option the most. She found that this feature made the text very clear and visible. She also liked having the ability to change the colour and to switch the tool on and off. She asked to have a copy of the extension.

Participant 6: This participant liked the idea of using the coloured filter because he believed that that many dyslexic users suffer from problems with brightness, thus using the filter is more likely to make the reading process easier.

2. Users without dyslexia

Participant 1: This participant found that using the tool made reading tabular-structured data easier. Nevertheless, the mean of the time taken to complete the task of reading the table with the tool was 9.14, and without the tool, the mean was 6.96. The participant completed the task easily and liked the idea of allowing the colours to be changed across the whole page. She also liked the way of moving the second row. She suggested changing the location of the option to move the first transparent row.

Participant 2: This participant strongly liked using the tool to read the tabular-structured data. The average time spent reading the tables of data using the tool was 8.63, and without using the tool, it was 15.74. The difference can be considered significant and supported the participant's opinion. She liked the flexibility of selecting the colours and the assistance which the tool gave her; however, she found some tasks hard to complete. Accordingly, she suggested that some instructions be added to make it easier for her to complete tasks.

Participant 3: The participant liked the idea of focusing on the row that needs to be read. She thought that the tool helped her somewhat to read the table. The mean of the time taken to read the table of data with the tool was 11.89, and without the tool, it was 13.20. Notwithstanding, like the majority of users, she felt that the tool could be improved by moving the option used to change the position of the first transparent row.

Participant 4: This participant was a lecturer at a university. She liked the assistance that the tool provided and found that the tool made reading tabular-structured data easier, especially when editing students' marks. The mean of the time taken to read the data table by this participant was 7.37 when using the tool and 11.63 without using the tool. She liked the feature for moving the rows and did not think the tool needed to be changed. She did, however, recommend that instructions be added or a help guide provided to support the use of the tool.

Participant 5: This participant found that the tool helped her to read the table of data, and it made the reading process more enjoyable. She felt, however, that she would not use the tool frequently because she perceived it as an extra task. The mean of the time taken to read when using the tool was 8.97, and without the tool, the time was 8.78. She liked the colours but disliked the moving options. She suggested adding an icon with four arrows next to each row. These arrows could be used to set up the transparent rows.

Participant 6: This participant found the tool useful as it enhanced the reading process for tabular-structured data. The mean of the time taken to read the given data was 7.24 when using the tool and 15.65 without the tool. This participant had the ability to complete all the tasks without any difficulty. He thought that the tool was good enough and did not offer any suggestions to improve it. He liked the colours and the way of moving the transparent rows the most.