An Empirical Investigation of Ways in Which Some of the Problems Encountered by Some Dyslexics May be Alleviated using Computer Techniques

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ABSTRACT

This research describes the development of a highly configurable word processing environment to alleviate some of the difficulties encountered by dyslexics when producing and reading text. It also describes a pragmatic, empirical methodology, closely involving dyslexic users, which has proved highly effective.

All dyslexic subjects tested were able to use the software to identify and store a configuration of background and foreground colour, text typeface and font, and spacing between characters, words and lines which they found easier to read than the default settings. Successful tests were also carried out to investigate the use of different appearances (font, colour etc.) to alleviate character recognition and reversal problems.

Keywords

Dyslexia, user-centred design, configuration, word processing

IINTRODUCTION AND BACKGROUND

This paper has two foci: firstly, it concerns the development of a word processing environment which is designed to alleviate some of the visual problems encountered by some dyslexics when they read and produce text; secondly, it describes the pragmatic, empirical approach which was taken to the development of a partial aid to a partially understood problem. The findings which are reported here are qualitative and will be tested experimentally at a later stage to provide empirical evidence in their support: the strategy adopted was to proceed on the basis of qualitative findings so as to maximise the rate of development in the early stages of the project.

In the absence of a full understanding of the nature of dyslexia, the researchers' approach was to identify some of the most commonly noted problems which dyslexics encounter when reading and producing text. On the basis of these common difficulties, they identified ways in which each individual might be able to minimise the consequences of their own particular problems by manipulating the appearance of their word processing environment and text presented within it. This stage of the development process involved the start of an iterative cycle of user-centred prototype development and evaluation with dyslexic computer users. The work in progress ultimately led to a software system which provides a highly (and easily) configurable environment for dyslexic people to use for reading and producing text. The researchers' approach has been to examine the parameters of the situation, including cost, cost benefit, existing software and user demand, with a view to finding an optimal path to the production of a software system which is of real use in practical situations. The general approach has led not only to a useful product but also to some promising avenues for future development, a few surprises and has identified those ideas which proved to be less promising than at first thought.

Dyslexia

Dyslexia is a language disorder which is very difficult to define and which has, as a consequence, had many definitions. The fact that dyslexia has had no single clear definition is that the term has been, and in some cases still is, loosely applied to many varying cases of word dysfunction.

The terminology used varies with place and time, but the same lack of clarity continues to exist both at an institutional level and in the minds of the parents of children with language disorders.

In an attempt to give a clearer indication of what categorises a dyslexic person, the British Dyslexia Association offers this description:

 "A dyslexic person is one who has a specific language disability affecting spelling, reading and other language skills characterised by a discrepancy between his (her) mental potential and his (her) education level despite conventional classroom instruction and despite absence of any primary emotional trouble or adverse environmental condition"

The symptoms of dyslexia vary greatly and the reasons for the existence of these symptoms are also varied. However, two distinct types of dyslexia are recognised: **acquired** dyslexia and **developmental** dyslexia.

Acquired dyslexia is associated with those people who have difficulties caused by damage to the brain. Therefore, prior to the occurrence of brain damage, no difficulties would have been identified. This area can be subdivided into disorders in which the visual analysis system is damaged - peripheral dyslexia, and disorders in which processes beyond the visual analysis system are damaged, resulting in difficulties affecting the comprehension and/or pronunciation of written words - central dyslexia.

Peripheral dyslexia is associated with difficulties such as misreading letters within words and migrating letters between words. Central dyslexia on the other hand concerns issues such as bad comprehension due to an impaired semantic system, and the inability to read unfamiliar words, whilst familiar words are read easily. Examples would include 'monkey' being read as 'ape' (a semantic error), and 'patient' being read as 'parent' (a visual error).

Developmental dyslexia, which is sometimes known as congenital dyslexia, exists from birth. It has been described as follows:

"Developmental dyslexia is a learning disability which initially shows itself by difficulty in learning to read, and later by erratic spelling and by lack of facility in manipulating written as opposed to spoken words. The condition is cognitive in essence, and usually genetically determined. It is not due to intellectual inadequacy or to lack of sociocultural opportunity, or to emotional factors, or to any known structural brain defect." [1]

One of the main features of dyslexia is the individual nature of the disorder. The condition is not typically characterised by one single difficulty, but by a range of difficulties which will vary in combination and in intensity between individuals, giving rise to an enormous variation between individuals in the problems encountered. Each dyslexic person has a range of difficulties which need to be addressed differently from other dyslexic people.

Technological assistance
The wide ranging characteristics of dyslexia provide a challenge for technological assistance, as a single approach will not be appropriate for the range of problems presented by a group of dyslexic people.

The current research therefore adopted a pragmatic approach to the design and development of a reading and word processing aid for dyslexic computer users. Computer technology offers the opportunity to provide reading and writing systems which are highly configurable for each individual user but they need to be based on an understanding of the problems which dyslexics have in reading and writing, and some of the visual problems which can affect them. The approach adopted in this research has been to offer dyslexic users a range of appropriate visual settings for the display of a word processor, together with the opportunity to easily configure the way in which text is displayed to them: the user can select, by experimentation, the settings which best suit them: these settings are then saved and later recalled each time that person uses the word processor. It will be seen that this approach affords the potential to make computer based text significantly easier to read than printed text, as well as improving the usability of computer word processing systems for dyslexics.

Some common problems of dyslexia.
It was first necessary to determine the parameters of the computer display which should be offered for configuration by the user. An initial investigation revealed that some of the most commonly encountered problems are as follows (adapted from [5] and Shaw, D. 1994, private communication) :

1. Number and letter recognition.
2. Letter reversals.
3. Word recognition.
4. Number, letter and word recollection.
5. Spelling problems.
6. Punctuation recognition.
7. Fixation problems.
8. Word additions and omissions.
9. Poor comprehension.

1. Number and letter recognition.
One of the fundamental problems faced by dyslexics is the recognition of alphanumeric symbols. This is often seen when letters which are similar in shape, such as 'n' and 'h', 'f' and 't', are confused. The problem is exacerbated with the introduction of uppercase letters. In addition, many dyslexic adults, who are capable of reading printed letters, have difficulty in reading cursive writing.

2. Letter reversals.
Many dyslexics are prone to reversing letters, which results in a particular letter being interpreted as another letter. Examples of these characters would be 'b', 'd', 'p' and 'q'. This problem can result in poor word recognition with words containing reversal characters being substituted for other words such as 'bad' for 'dad'.

3. Word recognition.

As well as the substitution effect caused as a result of letter reversals, words which have similar outline shape can be substituted by dyslexics. A typical example of this problem are the words 'either' and 'enter'. Both words have the same start and finishing characters and this, allied with the fact that both words also have the same overall shape, make them candidates for being substituted for each other when they occur in the text.

4. Number, letter and word recollection.

Even once the ability to recognise numbers and letters is mastered, it can still prove difficult for a dyslexic individual to recall the actual form and shape of a character. Many dyslexics have so much difficulty recalling upper and lower case characters that they continue to print later in life. Similarly, poor visual memory means that dyslexics have little ability to distinguish whether or not a word 'looks right' or not.

5. Spelling problems.

Due to the problems discussed in (1) - (4) above, dyslexics can have great difficulty with spelling and many dyslexics have very poor spelling. Much of the spelling of dyslexics appears to reflect a phonic strategy with words like 'of' and 'all' being spelt 'ov' and 'olh'.

6. Punctuation recognition.

As with characters, dyslexics appear to have difficulty recognising punctuation.

7. Fixation problems.

Another problem which is found in many dyslexics is their lack of ability to scan text without losing their place. Many find it difficult to move from the end of one line to the beginning of the next and also find themselves 'getting lost' in the text.

8. Word additions and omissions.

Dyslexics may add or remove words from a passage of text, apparently at random. This is manifested by words being duplicated, extra words being added, or word order being reversed.

9. Poor comprehension.

With the variety of errors caused by the factors described above, a dyslexic person may read a totally different passage of text from the one which is actually in front of them. Dyslexics thus display poor comprehension skills due to text which they perceive being significantly different from the actual text.

It is interesting to note that a minor version of this effect can also occur in normal readers, who can completely miss typographic errors. In this case however reading comprehension is usually improved.

Computer aid for the problems of dyslexia

In an attempt to alleviate some of the problems discussed above, dyslexics, particularly within the education system, are encouraged to use computers for text manipulation. The use of a computer keyboard has the potential to alleviate the problems of character recollection. If a person is capable of recognising the characters as they are on the keyboard, the need for the individual to recall the shape of the required character is no longer necessary, although since keyboard characters are normally uppercase this is less useful. In addition, however, the position of each character on the keyboard can be used to help recognition: as with touch-typing, to print an 'a' the user only has to remember to move to the left middle of the keyboard without having to recall the shape or form of an 'a'. The keyboard, however, only really helps with the recollection of characters, not the recognition of them once they are on the screen.

Another obvious facility already offered by word processors which can be of benefit to a dyslexic is the spell checking facilities. As discussed, spelling is an area which can cause great difficulty with dyslexics. However merely highlighting an incorrect word and offering a replacement may not be enough, since one of the other problems which some dyslexics face is an inability to tell if a word 'looks right'. They would therefore be unable to tell what was wrong with the badly spelt word and hence would be unable to correct the errors. There is, however, strong evidence to suggest that the use of lexical and spelling aids can greatly assist with spelling problems exhibited by dyslexics [4]. Many word processors now have grammar checking facilities which can be effective in picking out duplicate words and may also be of use in discovering word additions and omissions but, as with the spell checker, merely picking out these errors may not be enough because the dyslexic may be incapable of selecting the appropriate corrections.

It is also well known that some dyslexics are sensitive to colour, and that lighting conditions can be very important to their ability to read text. Some dyslexics either wear tinted glasses, or read text through a coloured acetate screen which is placed over the text. This suggests that manipulation of colour might be a valid configuration parameter. Many dyslexics also report interference from peripheral vision, indicating that anything that can be done to reduce screen "clutter" outside the main screen window, such as making the document "page" fill the whole screen may be of benefit (Shaw, D. 1996, private communication).

The approach taken in the current research was to investigate ways in which reading and document production could be improved for dyslexics through making **visual** changes to the environment in which the dyslexic is working, and by providing an easy-to use interface for dyslexics to configure this environment to their own particular preferences. This approach recognises the diversity of individual differences within the dyslexic community. A diagnostic system could have been developed for use with dyslexics, in which a variety of tests were performed, and conclusions drawn, which led to a third party setting up an optimised word processing system for each individual dyslexic. The researchers, however,

believed that by presenting a configuration interface to the individual dyslexic which was easy to manipulate and which enabled the user to see the consequences of various changes before accepting them, they would produce a system which not only left the user in control, but which also could give rise to a wealth of research data upon which to build future system improvements.

From the above discussion of the difficulties encountered by dyslexics, there are a number of approaches to manipulating the screen image of the text which might be of benefit in making it easier to read and produce. For example, enabling the manipulation of foreground and background colour, character typeface, font and spacing according to individual preferences may be beneficial. Difficulties caused by confusing similar letters and reversing others might be alleviated to some extent by making them look more distinguishable by using different typeface, font and/or colour. A parallel approach might be taken to similar shaped words. Fixation problems might be alleviated by, for example, presenting text in narrower columns, or with different spacings between words or lines. The researchers' approach was to investigate potentially promising ideas such as these by implementing prototypes and evaluating their utility with dyslexic users, with an overall view to developing a configuration system which will enable all dyslexics to set up their own optimised environment for reading and producing text by manipulating a potentially wide variety of individual display parameters.

AN EXPERIMENTAL TEXT READER FOR DYSLEXICS.
The first stage of the research was to develop an experimental text reader. This prototype presented the user with an easily configurable interface which allowed for a number of display variables to be altered. Initially, these were background, foreground and text colours, font size and style, and the spacing between paragraphs, words and characters. The interface was designed in such a way that it gave visual feedback on selections before they were confirmed and made minimal use of text instruction.

User evaluation (1)
Twelve computer literate dyslexic students from higher education with an age range of approximately 18 - 30 were engaged to assist by providing evaluative feedback throughout the development of the system. The dyslexic subjects were from varying backgrounds and with varying levels of dyslexia. Evaluative data was gathered by using "think-aloud" techniques, as well as by the use of questionnaires and interviews.

At the various development stages, the helpers were asked to try out the system with a view to seeing if it was possible for them to put together a display which improved their ability to read text from the screen. All the users were able to find a setting which was subjectively superior for them to standard black text on a white background with Times Roman 10 or 12 point text. The screen layouts which were developed by the test subjects were extremely varied, which highlighted the individual nature of the disorder.

Each person appeared to have his/her own favourite colour combination, although brown text on a murky green background was liked by all the testers even if no-one felt it was best. When asked about their choice of colours, some subjects said that the reason for their apparently surprising preferences was that the combination produced less contrast and was thus more restful on the eye. Some subjects reported that they were able to read better with their own colour settings, an observation which will be checked experimentally.

Subjects were in greatest agreement about the selection of a typeface: the sans-serif Arial was rated the best by almost all the testers. The reason given was that it was due to its simplicity. It was described by the various testers as a "straightforward", "very clear", "basic and rounded" font and was preferred to the more "flowery", "complicated" fonts. It was also felt by most of the testers that applying bold to the text had a negative effect, possibly because the letters "appeared more squashed together" and most testers selected a character size larger than the system's default 12 point.

All seemed to think that increasing the spacing between the characters, words and lines was beneficial, with one subject stating that he tended to read two words as one if the spacing was too small.

Perhaps the most interesting point which arose during the testing, and certainly the most promising for the researchers was the fact that at the beginning of the evaluation period the dyslexic subjects did not appear to be aware that altering these variables might be of any use. Most had assumed that the default settings of their word processor would be best and "got on" as best they could. The finding that all the subjects were able to find settings which were better for them than the default was important.

Evaluation of the initial prototype thus gave rise to some encouraging findings. These led to significant improvements in its design and provided the impetus for the development of a second prototype.

A TEXT READING AND EDITING ENVIRONMENT FOR DYSLEXICS.
The findings based on the first prototype system that indicated that there were potentially significant benefits for dyslexics from having a highly configurable interface for text reading. By this stage, the researchers knew that a promising line of enquiry had been found and that it would be worth carrying out further development using an evolutionary system, rather than the initial fixed prototype. It was clear that there would be a substantial advantage in developing a "dyslexic configuration" add-in for an industry standard word processor, since then the configurable interface could be used not just for text reading, but also for document production without the

necessity of writing a specialised complete word processing package. However, this design decision raises an interesting deviation from the received wisdom of the desirability of WYSIWYG (What You See Is What You Get): in the case of a dyslexic user, what you **see** should be whatever you can read best (i.e. your own personally configured environment), whereas what you **get** should be documents which are printed on paper in a more conventionally accepted layout. Print previewing facilities however provide a method of showing how the layout will appear when printed. Using a conventional word processor, the dyslexic user could use their own configured environment for document production, editing and reading, have the system (optionally) rearrange the material for printing in a more conventional layout and use the print preview facilities to do a final check on layout.

The next stage of the research programme therefore was the development of a second prototype which had all the features of the first prototype, but used Word for Windows [2] macros [3] to provide the required configuration interfaces.

At this stage further configurable parameter was implemented to test whether any assistance could be given to make character reversals less likely to cause problems. One pragmatic strategy for alleviating the letter reversal (e.g. 'b', 'd') problem would be to enable the dyslexic user (or an assistant) to inform the system of their particular reversal problems and alter the appearance of one or both of the reversal pair so that they are visually less similar. This might be done by using different colours, fonts or even sizes for each member of the pair. Since the reversal problem contributes to other associated problems (of which spelling is one), providing a way to distinguish between reversal characters might be expected to achieve an improvement in reading performance. The software implemented a number of possibilities: the first was to distinguish the characters making up the reversal problem by displaying them in different colours; the second was to separate them using different fonts and the third was to display them in different font sizes. This idea of colouring reversal characters provided very interesting and unanticipated results, which are described below.

Another problem which was tackled at this stage was the fixation problem. It was suggested that reducing the width of a page may provide a major benefit to those dyslexics who suffer from fixation problems: a facility to allow the user to easily alter this setting was included.

Finally, a facility to read text from the screen using a speech synthesiser was included on the basis that if the dyslexic user has fully configured their environment visually and is still having difficulties reading from the screen then having the text spoken will provide additional assistance.

The present version of the system incorporates all of the above ideas. There are two distinct parts to the overall solution, a "preference" program and a reading/editing program. The first allows users to experiment with the various parameters and determine the optimum values for them by selecting from an easy to use interface, and the second makes use of these preferences to assist the user in reading and editing future documents. In effect, the user creates within a word processing environment his/her own environment by setting their preferences using the *Preference* program and then uses the *Reading/Editing* program for all their word-processing.

The preference program menu presents the user with the option to vary the settings of colours (background, foreground), spacing (character, line, paragraph), column width, font (style, size, bold on/off) and reversal characters. When selected, each of the options presents the user with a means of adjusting the relevant variable(s) and includes a preview facility which displays the effect that the current set of changes would have on a standard document. When the user is satisfied with the settings he/she has chosen, the settings are stored in a "preferences" file for later recall by that user.

The reading/editing program allows the user to make use of the preferences file and also presents the user with an added toolbar which offers a number of options:

- Format document (using the "preferences" file),
- Return formatting to normal document (using a standard template),
- Return to preference program (to alter settings/build another file etc.),
- Return to reading/editing program (to continue editing),
- Print document (see below),
- Speak text.

The fact that a unique user environment, tailored to the need of each individual is provided, means that the document is (deliberately) not WYSIWYG. Users can prepare the text while viewing a document which is formatted specifically for them, but this is not the way they would wish for others to view their documents, especially when printed. For this reason, a print option which allows the user to print the document as it appeared with special formatting applied to it, or as it would appear without any special formatting, is part of the reading/editing program.

The "speak" function gives the user a number of options: The user can highlight any section of text and choose the speak option to have this text spoken. If no text was selected, pressing the speak option gives the user the option of speaking the character after the insertion point, the word which included the insertion point, the sentence which included the insertion point or the whole document. Testing this option with users indicated that speech would be very

important in a system of this nature. It provides another solution to the recognition difficulties of dyslexics, together with another means of identifying badly spelt words. In addition it allows the user to learn the correct pronunciation of multisyllabic words.

The system was developed as an add-on module to Microsoft Word 6/7, thus providing the benefit of an industry standard word processing system which included functions (as described above) which may also be of assistance to dyslexic users. This second prototype was evaluated with dyslexic subjects.

User evaluation (2)

Testing was conducted in a similar fashion to the earlier prototype. Questions were prepared and the testers were asked to evaluate the options to judge whether or not they could improve their reading ability with the aid of the system. Only one of the testers had been involved in the first evaluation.

Seven dyslexic users were tested who had different problems and to varying degrees. Three of the testers were from a local school, two aged 15 and the other 14, while three of the other four were in their twenties. One subject was over 30.

One of the testers was found to have reading difficulties mainly due to background glare. The others all expressed problems ranging from general reading difficulties and spelling problems to reversal problems, fixation problems and difficulty in pronouncing certain words. One tester normally used background and foreground colours which she discovered through testing the first prototype and two testers had previously tried coloured filters. None of the others used any method to reduce their problems other than the spelling/grammar check facilities. All of the testers had computing experience and were familiar with Microsoft Word.

In general each of the users found the system easy and intuitive to use with testers reporting that each of the options had an effect on the their ability to read. This supported earlier findings with the first prototype.

Colour
The options which allowed the user to change the colour scheme of the document appeared to be the most helpful and provided the best subjective improvement in reading ability. Again the colour schemes developed were varied.

Size and spacing
One tester stated that increasing the size of the text and being able to increase the various spacing values was the best thing about the system. All testers preferred to use a larger text size than the default.

The spacing option was implemented in such a way that as well as increasing the spacing between words, the spacing between characters within words was also increased. Some testers felt that this was a good thing while others did not

like it. To a certain extent spacing the characters made the word "clearer" but it had the drawback of distorting the overall shape of the word, a feature which some dyslexics rely on to identify the word.

Column width
The column width option certainly appeared to work very well with those who had fixation problems. The person with the least reading difficulties was the only person who did not report any improvement by altering the width of the column.

Reversals
The reversals option provided the most interesting results of all. Again, only the person with the least difficulties felt that colouring the reversal characters made the document more difficult to read. The others felt this option improved the display of the document greatly and appeared to be more impressed with this option than any other. The reason for the improvement however was not always that the reversal characters were clearly distinguished and easy to read. Instead it was claimed that the sporadic colouring "broke the text up" and resulted in the user being less likely to "get lost"; i.e. the system was reducing fixation problems rather than recognition problems.

As the testing progressed the testers appeared to be surprised at times by the effect some of the changes had on their ability to read the document. Colouring the reversals characters provided the most noticeable response but all of the options appeared to surprise the testers. "I would never have thought of doing that", one said after using the background/foreground colouring, and another stated, "I don't think that will do me much good" before he used the column width option, only to find it did help with fixation problems. All the test subjects appeared to be unaware of how simple changes could dramatically affect their ability to read.

CONCLUSIONS.

Throughout the development of both prototypes many interesting points emerged, largely as a consequence of adopting a pragmatic, empirical approach. Firstly, the fact that dyslexia is a very individual disorder was very evident during the testing sessions. Some found options which were very helpful which others did not find worked as well for them and *vice versa*, and the various configurations developed which were tailored to the specific difficulties of the individual were very different. This highlights the need for a highly configurable word processing package and also the need to identify as many options as possible which might affect dyslexics' ability to read and provide these options for the user to alter. Another recurring theme has been that the users appeared to be unaware of how easy it was to improve their reading potential by changing visual aspects of the reading environment. Many of the options which were presented can be achieved (in some cases, with difficulty) in most standard word-processing packages but

very few of the testers had actually tried any adjustments prior to using this system.

The principal conclusion to be drawn from this research is that screen configuration to personal preferences can aid dyslexics' ability to read. It is also apparent that many of the variable parameters (such as text colour) which were found to be useful are already features of the software: users discovered their utility by the way in which the prototypes presented them in a focused way, and in a way which made them easy for dyslexic users to experiment with. The research has also shown that manipulation of other parameters such as character reversals is a promising line of enquiry for future work.

The major surprises to emerge from the research were the discovery of the preference for low colour contrast between text and background (such as brown on muddy green) and the finding while experimenting with character *reversals* that the changes made to the text to do this helped reading by providing *fixation* aids within the text.

From a human-computer interaction point of view, this project appears to be an area where making what you get quite deliberately **not** what you see (WYGINWYS) can have significant benefits.

The strategy which was adopted for development of the project – a user-centred, pragmatic approach with incremental development - has clearly led to some insights and findings which would not have emerged using other approaches, and the development of a prototype *because it might be helpful*, based on micro-treatments of a number of different observed problems which dyslexics have when reading and producing text, seems likely to continue to be productive.

In more general terms the system as built appears to be viewed favourably by those who have tested it. It is simple to use and adds on efficiently to the normal Word interface. Above all, it provides the user with an easily configurable environment which appears to assist in reading documents, whilst at the same time retaining the functionality of the word processing package itself.

WORK IN PROGRESS

This paper is a report on work in progress. It describes both the progress of a research and development project and the methodology used to carry it out. The software is currently undergoing further development so that it can be distributed widely as an enhancement to Word for dyslexic computer users.

In terms of future research, the reversals option has provided some most encouraging results both in terms of helping avoid reversals and of helping fixation, and this area could be the starting point for much further development of the current system, with distribution and evaluation conducted over the world wide web to utilise the potentially massive test base. In addition, more formal experiments will be conducted to provide empirical evidence to confirm the improvements in reading which have been reported qualitatively during the development phases of this project.

Development of a fully working system encompassing some of the ideas above may have wider reaching implications than just a dyslexic word processor. It may be true that to a certain degree everyone is prone to having dyslexic traits which make it difficult to read text, whether it be the fully diagnosed dyslexic, the elderly person who may be slightly visually impaired or a person who through lengthy exposure to textual documents, particularly those on a computer screen, develop reading difficulties. In other words, in developing a system specifically designed for the type of problems experienced by dyslexics, there is likely to be a more substantial benefit to a much wider section of society. In the future a dyslexic word processor may become the standard to which every word processor adheres.

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