Emerging Technology Enabling Dyslexia Users to Read and Perceive Written Text Correctly

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Abstract. Dyslexia is treated by many specialists as a cognitive impairment involving visual attention deficit. It may cause an image of letter rotation or overlapping. Both children and adults suffer from this disease, differing in individual needs and seriousness. With a growing amount of information being distributed digitally, there is a need to accommodate online text to dyslexic users. However, with different types of operating systems, web browsers and substantial dyslexia individualism, it is not easy to fully automatize such needs. We are developing an extension for Chrome browser which is based on our previous cognitive research and empirical data. Such an extension will allow users with dyslexia to accommodate web content with special fragmentation sign which demonstrably suppresses reading problems caused (not only) by dyslexia.

1 Introduction

Depending on the language examined and the statistical methods used, it is stated that 5 % to 20 % of people worldwide suffer from dyslexia and other reading disorders, although only some of them are diagnosed [1]. Dyslexia is categorized in the International Classification of Diseases (ICD) as a symbolic dysfunction and reading disorder [2]. Categorized as mentioned, dyslexia is the primary neurological cognitive disorder affecting brain parts and visual pathways [3]. The requirements of textual accessibility for people with dyslexia of various languages has not yet been properly established. The level of dyslexia problems is very much dependent on the profile of the language. The main problems that users with dyslexia deal with are letter reversal (especially mirror reverse) and lateral masking (overlapping and losing adjoining characters).

Accessibility to any kind of information available digitally nowadays is a key factor to the equality of rights, breaking down social barriers. Considering that study materials and daily news are very much accessible through the Internet, accommodating digital content to diversely disabled users must be seen as a natural thing.

Dyslexia is typical for its problem variability, or rather, individuality. Therefore, it is not easy to find a general solution for every user, it is quite a tangible and unbounded task for satisfying technical solutions. Also, people are dealing with reading problems for instance after brain surgery, brain tumors, epilepsy and so on. The need to accommodate text for different groups of people with reading difficulties is therefore crucial. To make graphemes easier to read and distinguish between the original and the reversed

grapheme, we are studying text processing ways and come up with new solutions. This paper describes an autonomous unit of such a solution – an extension designed for Chrome web browser, based on our previous empirical studies.

1.1 Phonetic and Anti-Phonetic Languages Restrictions

Phonetic languages have simple rules of pronunciation as opposed to non-phonetic languages. Languages that can be marked as phonetic are Czech, Slovakian, Finnish, less phonetic ones are Swedish, Norwegian, Turkish or Albanian. Some of the non-phonetic languages are for instance English or French [4]. To distinguish between more or less phonetic languages, e. g. language recognition system can be used together with phoneme orthography evaluation data (Fig. 1) [5].

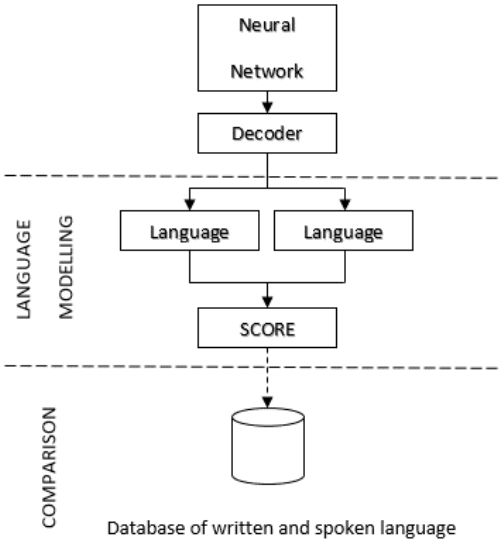

Fig. 1. Language model of phoneme recognition [5] adapted for phoneme-orthographic evaluation of languages and for further testing of usability of text modification hypothesis.

This is only one of the many reasons why different languages need different methods and approaches to the dyslexia solution and cannot apply general rules to all languages.

We are able to test our solution for dyslexic users also on the mentioned languages, as they contain problematic letters, which are pronounced phonetically (Table 1).

2 Related Work

To the best of our knowledge, there is no tool for accommodating web text as sophisticated as our proposed tool. Solutions used by dyslexic users are usually simple but not as interactive as necessary, not solving the real problems of dyslexia.

Table 1. The summary of languages and words with problematic (doubled) graphemes and its phonetic pronunciation – problematic letters do not change the pronunciation (ss→s etc.).

Language	Word	Pronunciation	English
Turkish	passerby	[pasrbai]	passerby
Albanian	hallkë	[halke]	ring
Dutch	sprookje	[sprokie]	fairy tale
Swedish	berättelse	[berætəlse]	tale
Norwegian	utdannelse	[ʉ:tdɑnəlse]	education
Finnish	tarkoittaa	[tarkoita]	mean

2.1 Plain text

One of the possible solutions tested within a group of people with dyslexia in the English language is the use of plain text with no graphical elements that may distract the user. The plain text also deals with font size and type (serif vs. sans serif) [6]. It is easy to change the font in some types of documents but as for technical aspects, still not every dyslexic user is able to change the font or disturbing visualization of a PDF or a web page.

2.2 Speech synthesis

Speech synthesis is often used to convert text to audio format [7]. There are studies which address this problem and propose solutions mainly for English [8, 9] and Spanish [10]. However, none of these solutions accommodate all aspects of dyslexia, moreover, due to grammar and word complexity of some languages, these applications are not helpful in specific societies. These systems are very much used in technologies helping blind or visually impaired people. A system that detects "difficult words" from a database and offers their synonyms was introduced in Spain and is being used in different platforms (for laptops, mobile phones, tablets etc.) [11].

2.3 Text4All

Text4All[1], designed by Topac [12] is a web page where a user types the url which he/she wants to visit and it restricts most of the graphics and structures the text in a very simple way. It may in some cases help a user to remove elements that are too disturbing (e. g. too many graphics) and make the text heavier (bigger letters, blanks etc.) but it may also eliminate important parts of such web pages (some graphic elements are crucial in study materials, instructions and even in daily news, Fig. 2). Because of changing the font, the web page sometimes causes letter overlapping which is unfortunately the problem that dyslexia causes (Fig. 3).

[1] http://www.text4all.net/dyswebxia.html

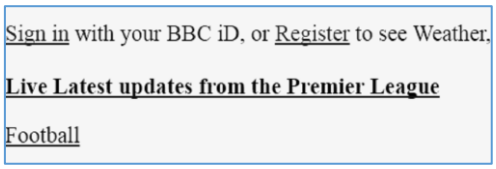

Fig. 2. Web page of BBC accommodated by Text4All – no pictures with articles.[2]

Fig. 3. Web page of University of Leeds accommodated by Text4All – overlapping text.[3]

2.4 Fox Replace

The extension for Mozilla Firefox permits changes in web page text by a manual insertion of any machine readable symbol - such an extra symbol is then always inserted into a specified place anywhere in a text (e. g. *i* between *m* and *n*). The problem with such an extension is that the rule that users manually set is applied to all content, including web page links. The result is that the link reports an error (Fig. 4).

2.5 Open Dyslexic

This is well-known extension at first built for Mozilla Firefox. Now, it is available for Chrome and Android as well. The idea is based on thickening the grapheme's curve to make confusing letters more distinguishable.

As stated before, the main problem of dyslexia dwells in visual attention, making the similar letters overlap, rotate etc. Thus, thickness of letters does not solve the problem. Moreover, the same parts of very similarly looking letters are thicker or thinner. Therefore, such text can still be hardly readable. Also, users that tried Open Dyslexic font have quite divergent opinions arising from their individual needs. "*The issue I have*

[2] http://www.text4all.net/do?url=www.bbc.co.uk&styleTextSize=22&op=dyswebxia2&styleTextColor=000000&styleBackground=FAFAC8&colors=000000_FAFAC8&styleTextFont=original&layout=original&lang=EN&langOp1=DifficultWords&langOp2=replaceNumbers

[3] http://www.text4all.net/do?url=www.leeds.ac.uk&styleTextSize=22&op=dyswebxia2&styleTextColor=000000&styleBackground=FAFAC8&colors=000000_FAFAC8&styleTextFont=original&layout=original&lang=EN&langOp1=DifficultWords&langOp2=replaceNumbers

with OpenDyslexic is that it has the bottom heavy theory which I feel does not do anything. You'll still flip the P and Q because they look so similar.", *". . . it was a relief to get back to a standard font after trying it out.*"[4]

Fig. 4. Extra symbol is being automatically inserted into web address which results in Error[5].

2.6 A Context-Aware Synonym Simplification

This extension for Chrome was meant to be a method that generates more simple synonyms of problematic words based on the context of the sentence. The database of synonyms was taken from Google Books N-gram Corpus and Open Thesaurus and presented in [13]. Authors argue that the extension, due to language mutations of the Corpus and Thesaurus, is easily transferable to other languages. Based on the published example (Fig. 5), some simplification might be misleading for the reader to understand the context properly. This can cause problems especially to students when reading study materials or important information of specific disciplines. Since the authors of the paper presenting CASSA tested this approach with only three volunteering subjects and do not present an argument of the functionality in other languages, it is questionable how practical this extension is in real use.

3 Reading Simplification Based on Grapheme Fragmentation

Our research focuses on building a huge fully-automatized and highly personalized system that would make digital text more accessible to people with dyslexia and other reading disorders. In this paper we present one part of such a system that is responsible

[4] https://nycdyslexiaresearch.wordpress.com/2012/10/12/is-open-dyslexic-font-actually-easier-to-read/

[5] www.bbc.co.uk/acc-es-sibi-l-ity, originally www.bbc.co.uk/accessibility

for the modification of web text. It is a Chrome browser extension and serves as an external part of the whole system, cooperating with its back-end (Fig. 6).

Original	El **contemplaba** en silencio aquella cruz.
	He was contemplating in silence that cross.
Baseline	Él **veía** en silencio aquella cruz.
	He was seeing in silence that cross.
LexSis	Él **consideraba** en silencio aquella cruz.
	He was considering in silence that cross.
CASSA	Él **miraba** en silencio aquella cruz.
	He was looking in silence that cross.

Fig. 5. Chosen words simplified by three different algorithms [13].

The main idea involves changing the visual perception of web pages on the user side. A hypothesis that inserting a fragmentation sign may help dyslexic users (both with developmental and secondary dyslexia) was preliminarily studied in Pařilová [14, 15] and Pařilová, Hladká and Bayer [16]. On ten volunteering subjects it shows that fragmentation has a potential to improve speed of reading while understanding of context is not disturbed (Tab. 2). There are no other works studying text fragmentation for dyslexic users but for instance larger spacing theory shows some improvement in reading, except in extensive texts it lacks of visual simplicity and intelligibility. Thus, the motivation for our work is to draw from empirical theories and establish innovative and significantly individual way of text accommodation.

User	Original/seconds	Modification/seconds
1	17,73	17,06
2	17,98	17,16
3	18,31	18,06
4	20,07	19,34
5	19,89	19,11
6	17,63	16,98
7	17,92	17,36
8	18,47	18,01
9	20,08	19,66
10	19,75	19,03

Table 2. Results of speed reading (and comprehension) testing [14].

The programming part of our extension is built on JavaScript. The extension works as follows.

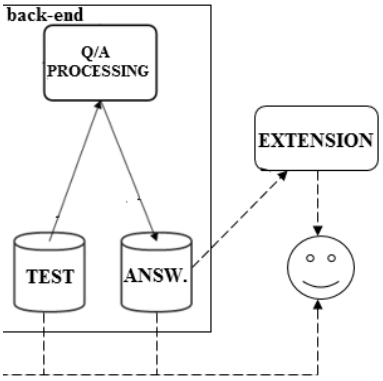

Fig. 6. Cooperation architecture between emerging system, the extension and a user.

3.2 Modification Process

To find the dyslexic user's needs to accommodate text, we use sets of tests available from the system (containing a database of similar tests). When a particular ID is sent to the server with a completed test, the server responds and the result is a matrix of letters that need to be divided. The "need" is set to a portion of errors made in test (e. g. *do divide top 30 % of errors made in the test*, Tab. 3).

The tests look like the following examples (Fig. 7, 8 and Tab. 4).

Table 3. Percentage of user's error possibly made in tests. Based on above results and set percentage the extension will modify patterns, e. g. *do* and *mn*.

Errors	%
mn	73
do	51
ce	24
tl	1

Fig. 7. Example of the test: Please mark the letter that is reversed.

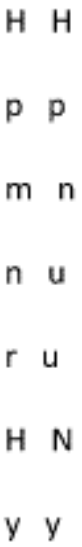

Fig. 8. Example of the test: please mark a pair of letters that seem to you not identical in the pair.

Table 4. Example of the test: Please find a word "mnul" (mark all 4 letters).

m	n	u	i	h
n	m	h	n	l
u	i	m	l	h
l	m	l	k	n
k	h	u	m	i

Jquery.min.js contains a JavaScript storage jQuery which is used for letter pattern searching and is implemented in background.js. The extension works on both http and https.

There are several ways to search for a grapheme pattern in a text, like SHIFT-OR algorithm, Aho-Corasick algorithm or Levenstein distance. However, we simply use regular expression advantages – fast processing, simplicity of use, possibility of case sensitivity adjustment, not too big dataset etc.

Regular expressions search for a defined letter pattern and divide it by the mentioned fragmenting sign – a dash. The searching runs only inside tags, tags themselves are not searched so that the visual shape of a piece of text changes but the content does not (Fig. 9, Fig. 10). Therefore, any text, including hypertext, can be more readable for the

user but the content of the page stays unchanged and after browsing any link and sub link is working properly (in contrast with Fox Replace).

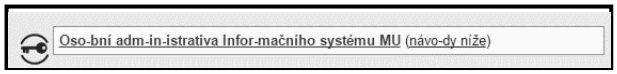

Fig. 9. Web page link after extension modification of Czech text.

Fig. 10. Correctly functional web page with no modification of the address.

Text in Finnish after the fragmentation would visually look like on Fig. 11, in Turkish on Fig. 12, in Bulgarian on Fig. 13, in Norwegian on Fig. 14 and in Swedish on Fig. 15.

```
Ihmisten ja tavaroiden vapa-a li-ik-kuvu-us tarkoit-ta-a...
Epidemia ylty-y, kun taud-inai-heut-taja pä-äse-e...
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Fig. 11. Part of Finnish text from university website.[6]

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...kuru-m-u-m-u-zun gelişimine bakı-l-dığında, bu kuru-mu-n...
...temel-lere oturtulm-uş ve devletin tan-ı-n-m-ışlığı...
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Fig. 12. Part of Turkish text from Ministry of foreign affairs website.[7]

Жен-и от ця-ла Б-ъл-гария на в-ъзраст до 35 годи-н-и.

… центъ-р в Б-ъл-гария… п-ъ-рвото у-чил-и-ще…

Fig. 13. Part of Bulgarian text from university web page.[8]

[6] https://www.helsinki.fi/fi/uutiset/epidemiat-tulevat-puskista
[7] http://diab.mfa.gov.tr/tr/hakkimizda/bakan/
[8] https://www.uni-sofia.bg/index.php/bul/universitet_t

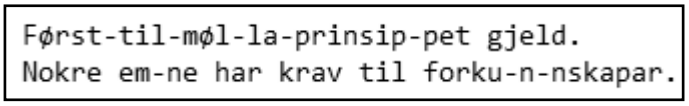

Fig. 14. Part of Norwegian text from university website.[9]

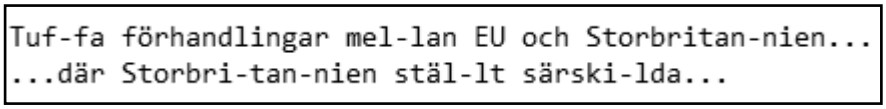

Fig. 15. Part of Swedish text from Ministry of affairs web pages.[10]

Conclusion

Dyslexia is a part of the cognitive disease group that affects both children and adults of any age. It can manifest after a surgery, tumors or brain injuries and can be temporary. However, most people with dyslexia appear to have lifelong lasting problems with decoding written text. For children it is necessary to train reading, because their brains are more plastic and accommodate much faster than adults' brains and their ability to read better and faster is expectable. But the same advice is true for adults – training is the only option to help improve reading. There were several attempts to use technologies for other impairments, for instance text to speech systems and screen readers [13], and also attempts to develop technology aimed at dyslexia. For web page reading, it is especially Fox Replace, the extension for Mozilla browser, Text4All web service and CASSA, the algorithm for simplifying sentences by using synonyms. However, none of the mentioned solutions is very comfortable or easily editable over time. The more information we find on the Internet (daily news, study materials, travel information, e-mail online box etc.), the more we need such a solution.

Our Chrome browser extension, autonomous part of an emerging service, focuses on individual needs and personalization of web pages. It is able to deal with transformation of one's need over time. It allows the user to use the extension on any computer as the extension is easily switchable and needs only one download. There is no need to sign up for the service which can be very much appreciated by its users (due to security of their personal data). This extension can be transferred to different (at least a little) phonetic languages. The extension is a challenge for further design and development of dyslexia assistive technology and offers the most up to date help that users with dyslexia may need while being online.

[9] http://www.uio.no/studier/admin/eksamen/tilrettelegging/
[10] http://www.regeringen.se/

Acknowledgements

The research and project work was done thank to "Representation of Czech Republic in European Research Consortium for Informatics and Mathematics" project ERCIM-CZ sponsored by the Ministry of Education, Youth and Sports, and with the support of the University Development fund FRVS/0430/2001 of the Masaryk University.

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