Graphical Schemes May Improve Readability but Not Understandability for People with Dyslexia

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Abstract

Generally, people with dyslexia are poor readers but strong visual thinkers. The use of graphical schemes for helping text comprehension is recommended in education manuals. This study explores the relation between text readability and the visual conceptual schemes which aim to make the text more clear for these specific target readers. Our results are based on a user study for Spanish native speakers through a group of twenty three dyslexic users and a control group of similar size. The data collected from our study combines qualitative data from questionnaires and quantitative data from tests carried out using eye tracking. The findings suggest that graphical schemes may help to improve readability for dyslexics but are, unexpectedly, counterproductive for understandability.

1 Introduction

Readability refers to the legibility of a text, that is, the ease with which text can be read. On the other hand, understandability refers to comprehensibility, the ease with which text can be understood. Since readability strongly affects text comprehension (Barzilay et al., 2002), sometimes both terms have been used interchangeably (Inui et al., 2003). However, previous research with dyslexic people have shown that both concepts need to be taken into consideration separately. For instance, while in dyslexic population reading, comprehension has been found to be independent of the spelling errors of the text; lexical quality can be used as an indicator of understandability for the non-dyslexic population (Rello and Baeza-Yates, 2012).

Dyslexia has been defined both as a specific reading disability (Vellutino et al., 2004) and as a learning disability (International Dyslexia Association, 2011). It is neurological in origin and it is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. Secondary consequences include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge (International Dyslexia Association, 2011).

On the other hand, the role of visual thinking is crucial in dyslexics and its development may be helpful for a number of tasks such as visual analysis and pattern recognition (West, 2009). Partially related to the importance of visual thinking in dyslexics, the use of graphical schemes has been an extensively recommended pedagogical strategy for dyslexic students (Ramírez Sánchez, 2011; Chalkley et al., 2001) as well as for students with reading disabilities (López Castro, 2010).

The inclusion of semantic maps was found to be beneficial for reading comprehension of general disabled readers in (Sinatra et al., 1984) and the inclusion of graphical schemes to improve comprehension for dyslexic readers has been proposed in (Weaver, 1978). However, to the best of our knowledge, no estimation of the effect of graphical schemes on the readability for dyslexics using eye tracking together with their effect in understandability has been done. Therefore, this paper presents the following three main contributions for Spanish na-

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tive speakers:

– An estimation of the effect of graphical schemes in the readability of dyslexic readers based on the analysis of an eye tracking user study.

– The relationship between readability and understandability in dyslexic readers using comprehension questionnaires.

– A survey conducted among dyslexics on the helpfulness of including graphical schemes.

The rest of the paper is organized as follows. Section 2 covers related work and Section 3 details the experimental methodology. Section 4 presents our results and in Section 5 conclusions and future challenges are drawn.

2 Related Work

We divide the related work in: (1) strategies used in discourse simplification for dyslexics, and (2) how these strategies were measured in relationship with readability and understandability.

Since dyslexics represent a target population of poor readers, different strategies have been applied for improving readability: the use of different text formats (Rello et al., 2012) and environments (Gregor and Newell, 2000), the use of multi-modal information (Kiraly and Ridge, 2001) and text to speech technologies (Elkind et al., 1993), among others. The closest work to ours is the incorporation of summaries and graphical schemes in texts. Previous work has shown that the readability of dyslexic students could be improved by using text summarization (Nandhini and Balasundaram, 2011) and semantic maps (Sinatra et al., 1984).

Various factors have been applied to measure readability in dyslexics. Classic readability measures are useful to find appropriate reading material for dyslexics (Kotula, 2003) and to measure comprehension. For instance, the Flesch-Kincaid readability degree was applied to access comprehension speeds and accuracy in dyslexic readers (Kurniawan and Conroy, 2006). Other specific readability measures for dyslexic readers have been proposed in other domains such as information retrieval (Sitbon and Bellot, 2008).

In the case of the use of summaries, the evaluation of comprehension was carried out using questionnaires (Nandhini and Balasundaram, 2011). Multiple choice questions were applied to measure the incorporation of semantic maps among disable readers (Sinatra et al., 1984) and eye tracking measures have been used to explore various characteristics related to dyslexic reading (Eden et al., 1994).

Although the creation of graphical schemes is extensively recommended in literature (Weaver, 1978; Ramírez Sánchez, 2011; López Castro, 2010), we found no formal evaluation of their impact in readability and comprehension combining data from eye tracking, questionnaires, and a survey.

3 Experimental Methodology

3.1 Participants

Twenty three native Spanish speakers with a confirmed diagnosis of dyslexia took part in the study, twelve of whom were female and eleven male. All the participants were asked to bring their diagnoses to the experiment. Their ages ranged from 13 to 37, with a mean age of 20.74. There were three participants with attention deficit disorder. All participants were frequent readers; eleven read less than four hours per day, nine read between four and eight hours per day, and three participants read more than eight hours daily. Ten people were studying or already finished university degrees, eleven were attending school or high school and two had no higher education. A control group of 23 participants without dyslexia and similar age average (20.91) also participated in the experiment.

3.2 Design

The experiment was composed of four parts: (1) an initial interview designed to collect demographic information, (2) a reading test, (3) two questionnaires designed to control the comprehension, and (4) a survey to know the impressions of each person regarding the inclusion of graphical schemes.

Along the reading test we collected the quantitative data to measure readability, with the comprehension questionnaires we measure understandability, while with the survey we gather information about the participant views.

We used two different variants (A and B) of the

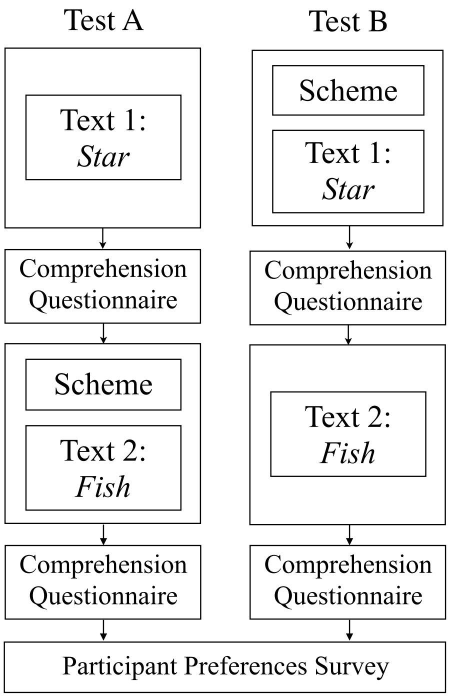

Figure 1: Variants of the experiment.

test (see Figure 1). Each test was composed of two texts: one text that included a graphical scheme in the top and another text without the graphical scheme. We extracted the most similar texts we could find from the Spanish Simplex corpus (Bott and Saggion, 2012). The chosen texts share the following characteristics:

(a) They both have the same genre: science news.

(b) They are about similar topics: Text 1 (called *Star*) is about the discovery of a supernova and text 2 (*Fish*) is about the discovery of a new species of fish.

(c) They contain the same number of sentences: 4 sentences in addition to the title.

(d) They have the same number of words (136).

(e) They have a similar average word length: 5.06 letters per word in *Star* and 5.12 letters per word in *Fish*.

(f) They contain the same number of unique named entities (7).

(g) They contain one foreign word: *Science* in *Star* and *Jean Gaudant* in *Fish*.

(h) They contain one number: *6.300 años luz* ('6,300 light years') in *Star* and *10 millones de años* ('10 millions of years') in *Fish*.

As seen in Figure 1, in variant A, text 2 includes a graphical scheme while text 1 was presented without the graphical scheme. Variant B is reversed: text 1 appeared with a graphical scheme and text 2 without it. The order of the experiments was counterbalanced using the variants A and B to guarantee that the participant never reads the same text twice.

For the layout of the texts and graphical schemes we chose a recommended font type for dyslexics, sans serif arial (Al-Wabil et al., 2007), unjustified text (Pedley, 2006), and recommended color and brightness contrast using a black font with creme background[1] (British Dyslexia Association, 2012).

For the creation of the graphical schemes[2] we took into account the pedagogical recommendations for dyslexics (Ramírez Sánchez, 2011; Chalkley et al., 2001), and the cognitive principles of inductive learning in concept acquisition from scheme theory (Anderson et al., 1979; Anderson and Robert, 2000). Since the tests were going to be read by dyslexics, the graphical schemes were manually created by a dyslexic adult and supervised by a psychologist. The graphical schemes simplify the discourse and highlight the most important information from the title and the content. Each of the graphical schemes shares the following pattern: the first line of the graphical scheme encloses the main words of the title connected by arrows and then, starting from the title, there is a node for each of the sentences of the text. These nodes summarize the most relevant information of the text, as the example translated to English shown in Figure 2. We present the original text and its translation in the Appendix.

To control the comprehension, after each text we designed a maximum performance questionnaire including inferential items related to the main idea. We did not include items related to details, because they involve memory more than comprehension (Sinatra et al., 1984). Each of the items had

[1]The CYMK are creme (FAFAC8) and black (000000). Color difference: 700, brightness difference: 244.

[2]Notice that we distinguish graphical schemes from conceptual graphs (Sowa, 1983) or semantic maps (Sinatra et al., 1984).

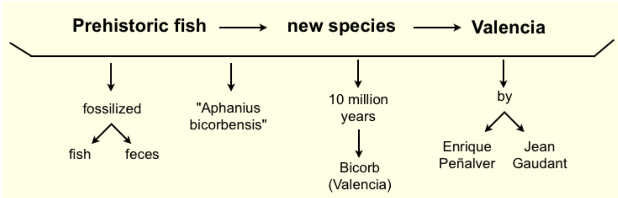

Figure 2: Example of a graphical scheme (*Fish*).

three answers, a correct one, another partially incorrect (normally containing details), and an incorrect one. We gave 100, 50, and 0 points for each type of answer, respectively. For instance (translated into English):

- What is the text about?
  - (a) About the National Museum of Natural History in Paris (0 points).
  - (b) About the discovery of a prehistoric fish in Valencia (100 points).
  - (c) About the content of the fish feces (50 points).

The test finishes with one survey to learn the participant preferences. The survey is composed of three items about how helpful was the graphical scheme for (1) reading, (2) understanding, and (3) remembering the text. Each item uses a Likert scale with 5 levels, from strongly disagree (1) to strongly agree (5). An example of an item follows:

- Without the graphical scheme, my understanding of the text would have been:
  1. Much more easier because I did not understand anything about the graphical scheme.
  2. Easier because the graphical scheme is complicated.
  3. Neither easier nor more difficult.
  4. More difficult because the graphical scheme has helped me.
  5. Much more difficult because the graphical scheme has shed light about the content.

3.3 Equipment

The eye tracker used was a Tobii T50 (Tobii Technology, 2005) with a 17-inch TFT monitor. The eye tracker was calibrated for each participant and the light focus was always in the same position. The distance between the participant and the eye tracker was constant (approximately 60 cm. or 24 in.) and controlled by using a fixed chair.

3.4 Procedure

The sessions were conducted at Pompeu Fabra University and they took around 30 minutes, depending on the amount of information given by the participant. In each session the participant was alone with the interviewer (first author) in the quiet room prepared for the study.

The first part began with an interview designed to collect demographic information. Second, we proceeded with the recordings of the passages using eye tracking. Half of the participants made variant A of the test and the other half variant B. The participant was asked to read the texts in silence and completing each comprehension questionnaire. The text ends by answering the survey.

3.5 Data Analysis

The software used for analyzing the eye tracking data was Tobii Studio 3.0 and the R 2.14.1 statistical software. The measures used for the comparison of the text passages were the means of the fixation duration and the total duration of reading. Differences between groups and parameter values were tested by means of a one-way analysis of variance (ANOVA).

4 Results

In this section we present first the analyses of the data from the eye tracking and comprehension questionnaires (Section 4.1), followed by the analysis of the survey (Section 4.2).

4.1 Readability and Understandability

To measure the impact of graphical schemes in readability we analyzed the means of the fixation time and the total reading duration of the passages. Shorter fixations are preferred to longer ones because according to previous studies (Just and Carpenter, 1980), readers make longer fixations at points where processing loads are greater. Also, shorter reading durations are preferred to longer ones since faster reading is related to more readable texts (Williams et al., 2003). We compare readability with understandability through the inferential items of the comprehension questionnaire.

First, we studied the differences between the dyslexic participants and the control group. Then,

Table 1: Experimental results of the eye-tracking and the comprehension user study.

Measure (sec., %) (ave. $\pm$ std.dev.)	Scheme + Text	Text
	Group D	
Fixations Duration	0.224 ± 0.046	0.248 ± 0.057
Visit Duration	64.747 ± 22.469	78.493 ± 34.639
Correct Answers	86.93%	97.73%
	Group N	
Fixations Duration	0.205 ± 0.033	0.198 ± 0.030
Visit Duration	43.771 ± 14.790	45.124 ± 13.353
Correct Answers	89.58%	95.83%

we analyzed the influence of the graphical schemes in the readability and understandability.

In (Kurniawan and Conroy, 2006) it was found that students with dyslexia are not slower in reading than students without dyslexia when the articles are presented in a dyslexia friendly colour scheme. However, we found statistical significance among the dyslexic and non-dyslexic groups when reading both texts without graphical schemes taking into account the mean of fixation time ($p < 0.0008$) and the total reading duration for the texts with graphical schemes ($p < 0.0007$) and without graphical schemes ($p < 0.0001$) (see Table 1). On the other hand, our results are consistent with other eye-tracking studies to diagnose dyslexia that found statistical differences among the two populations (Eden et al., 1994).

The presence of graphical schemes improves the readability of the text for people with dyslexia because the fixation time and the reading duration decreases for all texts with a graphical scheme (see Tables 1, 2, and 3). Notice that these positive results are given for the comparison of the texts alone (see the text areas in Figure 1). If we compare the total reading duration of the text alone with the text plus the graphical scheme, it takes in average 18.6% more time to read the whole slide than the text alone.

However, we found no statistically significant results among texts with and without graphical schemes using such measures. The greatest difference in readability among texts with and without graphical schemes was found taking into account the fixation times for both texts ($p = 0.146$) among the dyslexic participants.

Comparing both *Fish* and *Star* texts (see Tables 2 and 3), we observe that *Fish* was more difficult to read and understand since it presents longer fixations and a lower rate of correct answers. In dyslexics the fixation time decreases more (from 0.258 seconds without graphical scheme to 0.227 with a graphical scheme, $p < 0.228$) in *Fish* that in *Star* (0.237 to 0.222, $p < 0.405$), meaning that graphical schemes have a higher impact in readability for complex texts.

Considering the similarity of the texts, it is surprising how *Fish* seems to be easier to read than *Star*. One possible explanation is that the scientific piece of news contained in *Star* was more present in the media than the other news contained in *Fish*.

However, graphical schemes have not helped our participants to increase their rate of correct answers for the inferential items. For all the cases except one (non-dyslexic participants in *Star*, Table 2) the rate of correct answers decreased when the text was accompanied by a scheme.

Dyslexic participants have a higher percentage of correct answers than non-dyslexics when the text is presented with the graphical scheme, and lower rate if the text is presented without the graphical scheme. These results are consistent with some of the opinions that the participants expressed after the session. A few dyslexic participants explained that the graphical scheme actually distracted them from the text content. Another dyslexic participant exposed that the graphical schemes helped her to remember and study texts but not to understand them. The diverse opinions of the participants towards the graphical schemes suggest that normally graphical schemes are highly customized by the person that creates them and therefore a non-customized schema could complicate understandability.

4.2 Survey

Through the user survey we infer how the participants were influenced by the graphical schemes in: (1) the text's readability, (2) the understandability of the text, and (3) remembering the text content. In Figure 3 we present the results for each of the items comparing dyslexic and non-dyslexic participants ($N = 23$).

In terms of readability, dyslexic and non-dyslexic participants have opposite opinions. While dyslexic participants agree in finding graphical schemes help-

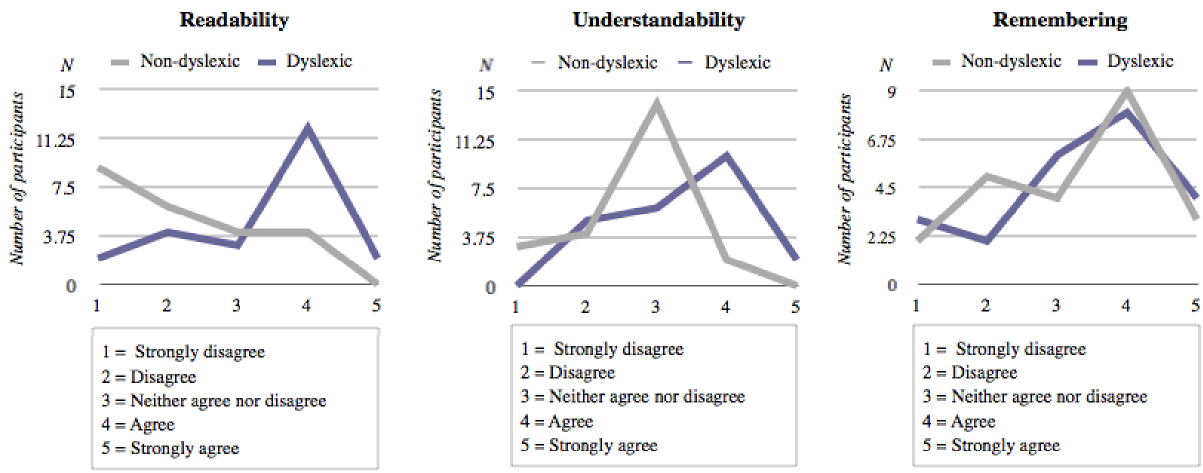

Figure 3: Survey results for understandability, readability and remembering.

Table 2: Experimental results of the eye-tracking and comprehension user study for text 1, *Star*.

Measure (sec., %) (ave. $\pm$ std.dev.)	Scheme + Text	Text
	Group D	
Fixations Duration	0.222 ± 0.061	0.237 ± 0.023
Visit Duration	63.633 ± 0.00	83.918 ± 18.606
Correct Answers	87.5%	95.45%
	Group N	
Fixations Duration	0.205 ± 0.023	0.199 ± 0.041
Visit Duration	39.552 ± 14.850	47.351 ± 15.580
Correct Answers	91.67%	91.67%

Table 3: Experimental results of the eye-tracking and comprehension user study for text 2, *Fish*.

Measure (sec., %) (ave. $\pm$ std.dev.)	Scheme + Text	Text
	Group D	
Fixations Duration	0.227 ± 0.026	0.258 ± 0.078
Visit Duration	60.073 ± 20.684	69.058 ± 29.910
Correct Answers	86.36%	100%
	Group N	
Fixations Duration	0.205 ± 0.042	0.214 ± 0.036
Visit Duration	47.990 ± 14.130	42.896 ± 10.991
Correct Answers	87.5%	100%

ful for reading (12 participants, 52.17%), non-dyslexic participants said that graphical schemes were unhelpful. Some participants explained that the graphical schemes mislead them because they were placed at the beginning of the slide when they did not know the topic of the text. However, a few participants claimed that they found the graphical schemes very helpful.

Participants with dyslexia mostly agree (10 participants, 43.48%) in finding graphical schemes helpful for textual comprehension while most of the non-dyslexic participants (14 participants, 60.87%) did not find graphical schemes neither helpful nor unhelpful for understandability. On the other hand, both populations agree in finding graphical schemes helpful for remembering data from the text.

5 Conclusions and Future Work

The addition of informational elements to a text impacts its readability. Since dyslexics are strong visual thinkers this study relates the use of graphical schemes to readability and understandability, contributing to predict their impact.

In general terms, we can affirm that adding a graphical scheme in a text improves its readability, since we observed a decrease in the fixation time and an increase of reading speed in texts containing graphical schemes. On the contrary to the expected result, understandability does not improve with the presence of graphical schemes.

Even though dyslexia presents heterogenous manifestations among subjects, we found patterns related to readability and understandability using quantitative and qualitative data.

However, our results shall be taken with care since readability, specially in dyslexic users, depends on many factors which are very challenging to control in an experimental setup. These factor include the vocabulary of the participants, their working memory or the different strategies they use to overcome dyslexia.

Further work is needed such as the inclusion of more types of graphical schemes in the experiments, the addition of a delayed post-test to address the effect of supplemental graphical schemes on robustness of learning, and the exploration of more factors related to readability.

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A Appendix

Below we present Text 2 (*Fish*) and its translation to English.

Descubren en Valencia una nueva especie de pez prehistórico

El estudio de un lago salino que existió hace 10 millones de años en Bicorb (Valencia) ha permitido descubrir el fósil de una nueva especie de pez prehistórico y de sus heces. Según informó este martes el Instituto Geológico y Minero de España, este pez depredador ha sido bautizado por los investigadores como "Aphanius bicorbensis", en honor a la población de Bicorb donde ha sido encontrado. La investigacin ha sido realizada por Enrique Peñalver, experto en insectos fósiles del Instituto Geológico y Minero, y por Jean Gaudant, especialista en peces fósiles del Museo Nacional de Historia Natural de París, gracias a la financiación de la Consejería de Cultura de la Generalitat Valenciana. El estudio del contenido de las heces de estos peces, que también quedaron fosilizadas en la roca, ha permitido a los investigadores saber que este depredador se alimentaba de los foraminíferos y de las larvas de mosquito, especialmente abundantes en el lago.

A new species of a prehistoric fish is discovered in Valencia

The study of a saline lake that existed 10 million years ago in Bicorb (Valencia) has uncovered the fossil of a new species of prehistoric fish and their feces. The Geological and Mining Institute of Spain informed last Tuesday that this predatory fish has been named by the researchers as "Aphanius bicorbensis" in honor of the town of Bicorb where was found. The research was conducted by Enrique Peñalver, an expert on insect fossils of the Geological and Mining Institute, and Jean Gaudant, a specialist in fossil fishes of the National Museum of Natural History in Paris, thanks to funding from the Council of Culture of the Government of Valencia. The study of the content of the feces of these fishes, which were also fossilized in the rock, has allowed researchers to know that this predator was feeding on foraminifera and mosquito larvae, especially abundant in the lake.