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The Influence of Line Length: A Pilot Study

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Abstract **-** The aim of this work is to understand the impact of typography on humans in terms of reading. Several tests were carried out to achieve the proposed objective of understanding the influence of different visual variables to ensure a more precise reading process. Four variables were studied using various sensors, such as the Brain Computer Interaction (BCI) device, to measure brain activity (active, neutral, and calm) and heart rate activity (HRA). The reading time and the number of errors were also considered. The results show that the visual variables have a different impact considering the type of text (scientific and children's text) as well as the reading medium (paper or screen). In addition, the results show that preferences vary according to the type of visual variables as predicted and as confirmed by the measurements taken during the reading process. However, oddly enough, the participants when questioned during the survey, their answers were not coincident by the measurement results. For this reason, this empirical study in interaction design is important as a future reference approach to the perceptibility and readability of text. On the other hand, the use of BCI and HRA parameters is not widely described in the literature. So, this paper allowed to perceive and identify the most adaptable typographic parameters both in the type of text and in the reading medium.

Keywords**:** HCI; Interaction design; Visual Variables; Design; BCI; HRA

1. Introduction

Typography is the building block of all written communication and is the design of arranging letters and text to make written language legible, readable, and appealing to the reader. Typography is a visual leader, so the reader can easily look around without getting lost or distracted. The use of typography in graphic design adds another way to communicate meaning through the visual aspects of text.

As a result of the many advances within the field of high technology, electronic devices are widely used on a daily basis when seeking any knowledge and allowed to test multiple typographic variables in combination and in their typical ranges rather than in possibly unrealistic configurations [1]. Several typographic variables displayed a significant effect on reading performance and on brain and heart rate activity.

It is by the means of this communication configuration that the interpretation of resulting data and its interconnections make it highly possible to understand clearly and to suppress any apparent ambiguity.

The concept "readable" is a generic act between authors and text readers. Some investigators believe in the relevance of a text to be understood and ensure that there are standards which exist to reject "unreadable" characters making it impossible for unrecognizable letters to appear in instances where communicability needs to be perceptible and without any hesitation[2]. Readability is defined as "the ease of understanding or to the style of writing."[3] and "ease of reading words and sentences," is an attribute of clarity. [2], [4]–[8]. Text's readability is influenced by both its presentation (such as font size, line height, character spacing, and line length) and content (such as the difficulty of its vocabulary and syntax) [8].

Visual variables have a crucial role in understanding reading performance and its significance in the history and contemporary practice of typography.

The literature investigates how visual factors affect readability, including how letters and words are perceived and how continuously reading text is read [9]–[11]]. The size and shape of printed symbols were studied, and it's concluded that these variables determine the legibility of text and there is present evidence supporting the hypothesis that the distribution of print sizes falls within the psychophysically defined range of fluent print size, i.e. the range where text can be read at maximum speed [11].

Also, an eye tracking study of how font size and font type affect online reading. The parameters computed to quantify the results were reading speed and post-tests of comprehension. The results show that for smaller font sizes, fixation durations are significantly longer, resulting in slower reading - but not significantly slower. There is also an important result described in which there were no significant differences in serif vs. sans serif fonts: serif reading was only slightly faster [12]. It is

fundamental to determine the shapes of both letters and words to understand the characteristic aspects of the words and to be able to read the text continuously with accuracy, ease, speed and understanding [9].

Another study clarifies that for this to happen various models are needed and used to calculate the behaviour of reading such as comprehending quickly; interpretation at a distance; peripheral vision and its perception; tired at reading; visibility; and the progression of eye movement. The impact of letter spacing on reading and the purification of the effect of confounding variables were measured, and from the results, the authors concluded that rapid recognition of close letter combinations plays a important role in word encoding[13].

In another study the results highlight the importance of low-level visual factors, corroborating the emphasis of recent psychological models on visual attention and crowding in reading, [1]. There are some studies that use sensors to evaluate the typography [12] namely the eye tracking to understand how font size and font type affect online reading [11], and to investigate the effects of typographical cueing and hierarchy on the reading patterns, recall, [14], [15] and for the comprehension of participants whose first language is not English presents how the technology of eye-tracker can be used to research typography and publication design for screen applications. The eye-tracking is also used to investigate whether increased attention leads to enhanced learning and investigated readers' preferences for specific textual features and compared these with eye tracking data to ascertain if features were effective in drawing reader's attention [10], [16]. The BCI sensor is used to obtain information about the users when reading several words written in different typefaces and deduce their mental states (fatigue, stress, immersion) through user's electroencephalogram signals (EEG) [17].

However, the question remains and continues to be asked, "Which is the better reading format, paper or screen?" With this doubt in mind, both the focus and the goal will be to understand and point out which is the preferred reading format [18]. The main goal of our study is understand which is the best format - printed text or its digital form?; if it is more beneficial to have one column or two; and if a scientific text or a children's text change presents different in terms of typography preferences.

Research from years ago regarding this matter concluded that reading on paper was the most favourite reading format when compared to a digital format, stressing the advantages of its printed format and its efficiency.

There are many scientific cases, for example, showing where techniques like the treatment of perceptive information and/or the process of turning or skipping pages just to name a few, are designated to be more accessible and understandable to the brain when processing and interpreting paper data [19].

Agreeing in-part yet not completely there are many situations where reading on the computer screen becomes more effective than in paper format expressing that in today's modern world there are materials which were thought of and produced with the intention of being understood when reading on a screen [20], which are the fundamental tools for an efficient digital reading: visualization of speculative notions or images, sense of orientation, formation of a presentation, possibility and availability of manifestations such as video tutorials, and the development of educational simulators and video games [20].

Another study in this field [21], also agrees regarding the comparison about the advantages between both types of readings (paper and digital) and concludes that no method is better than the other for understanding the information presented, however, there may be a preference for each of the ways of reading depending on the purpose previously defined for each reading behaviour. For example, if the context of reading is meant to be to learn about eCommerce, it can be more beneficial in digital format; but, if the reading is about a fictional circumstance, paper can be a more useful way of understanding all the details [21].

Previous investigations regarding the visual programming of texts, also agreed with them when emphasizing the fact that scientific texts should be read in two columns because it is considered advantageous for the reader to proceed more effectively with the reading process when presented with this type of reading format[19]–[21].

In this sense it is understandable that each author has a formed opinion to the preference of a reading mode because all of them have established their reasoning based upon and in reference to the many characteristic factors presented by each investigation.

Nonetheless, this research aimed to understand the different readings and the aspects associated with them (paper or digital; one or two columns; scientific or children's text) while also understanding the preferences of the participants with regards to their characteristics rather than the efficiency of the reading itself by the participants.

In our study, participants were asked to read texts while their heart rate activity and brain activity is recorded. Two texts were used on paper and on screen, to capture (part of) the natural variability of typographic factors. We assessed the impact of visuo-typographic variables on number of errors, time reading, heart rate- activity and brain activity. This paper is organized as follows: First, the introduction of the problem is done; second, the methods (participants, procedures and devices) are presented, after we have the results, and finally we present the discussions and some conclusions.

2. Methods

2.1. Participants and Procedures

This study took place over a period of two months in a quiet and familiar environment known to each participant for the sole purpose of providing comfort to obtain the most favourable results possible. Four sessions were held in which subjects of different nationalities and age groups participated ranging from 18 to 72 years old. Of the 24 participants (6 are men and 18 are women) with varying levels of education starting at the fourth grade to a doctorate's degree as well as possessing diverse professional backgrounds.

All participants provided written informed consent prior to the experimental session. The research has been conducted adhering to the ethical guidelines and the legal requirements of the country in which the study took place (Portugal).

2.2. Methodology

The experiment was done considering the follow strategy: scientific or children's texts, printed or digital and wishes to reveal the most favourite types and forms of selected reading material by studying the data collected when testing its participants and by understanding said reading selections with the utmost of comprehension.

Before the experiment, a survey was carried out on each user to determine whether the participants had any specific reading habits, if they wore glasses or not, if they knew of any other aspects or wished to give any relevant input regarding this study and its overall execution.

A specific reading order of the documents in their entirety was established so that each participant followed the same reading sequence as purposed. In closing, one last questionnaire was conducted for understanding the participants' preferences and their opinions regarding the texts they read and to the manner the experiment was handled.

Experiment - Line Length: one or two columns:

- Children's text on paper divided in one column: Ch_paper_#1
- Scientific text on screen in one column: Sc_screen#1
- Children's text on screen divided in two columns: Ch_screen_#2
- Scientific text on paper divided in two columns: Sc_paper_#2
- Children's text on screen in one column: Ch_screen_#2
- Scientific text on screen divided in two columns: Sc_screen_#2
- Children's text on paper in one column: Ch_paper_#2
- Scientific text on paper in one column: Sc_paper_#1

2.3. Devices

In this work two different devices were used to collect the biological signal: Muse headset (see https://choosemuse.com/) and Polar Smart Watch (see https://www.polar.com/us-en/products/heart-rate-sensors/).

Muse is a Brain Sensing Headband [22], which allowed to collect data on the active, calm, and neutral values by measuring the brain wave signals of the participants, while doing the two experiments. The BCIS have the functionality use to measure brain activities of a user thus allowing to identify the pattern of a certain action or thought [23]. The system uses advanced signal processing algorithms to train beginners and intermediate meditators to control their focus. This device

detects brain electrical activities and turns them into easily understandable experiences. This equipment comes with a Headband, which is placed on the forehead of the participant, with the purpose of detecting brain electrical activities. It only possible to detect through the 7 brain sensors EEG (electrical braingraph) if they are calibrated: 2 in the forehead, behind the ears and 3 reference sensors - that detect and measure the activity of the brain.

The Polar Smart Watch [24] is a Heart Rate Sensors that monitoring the heart activity, namely, the minimum, average and maximum value of heart rate. Smartwatches have the capability to collect data in a continuous manner and have been used in research on behaviours and mobility patterns [24], [25].

3. Results

The analysis was made considering different parameters, muse parameters, polar smart watch parameters, and the time reading. We used the Wilcoxon test, (a non-parametric test) for the statistical comparisons of the average of all variables. A significance of 95% was considered.

It is possible to observe the differences in the reading time between Children Text (right graphic) and Scientific Text (left graphic), in paper and in screen considering one and two columns (Figure 1).

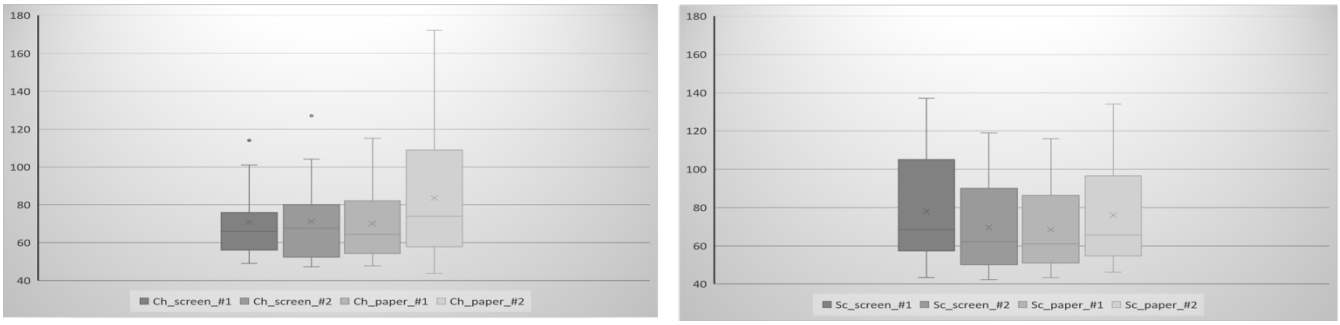

Figure 1 Reading Time in seconds of Children Text (left graphic) and Scientific Text (right graphic), in paper and in screen considering.

The table 1, show the statistically comparison of the results (Figure 1), and significative differences were found.

Table 1 Statistically comparison of Time Reading Children Text and Scientific Text, in paper and in screen considering one and two columns.

	Sc_screen_#1	Sc_screen_#2	Sc_paper_#1	Sc_paper_#2	Ch_screen_#1	Ch_screen_#2	Ch_paper_#1	Ch_paper_#2
Sc_screen_#1		0,001864742	0,000205457	0,425428185	0,042993318	0,021275651	0,009387799	0,082435577
Sc_screen_#2	0,001864742		0,499867156	0,034377717	0,648520899	0,518123248	0,794820213	0,001913056
Sc_paper_#1	0,000205457	0,499867156		0,00342926	0,327711229	0,20841989	0,365357348	0,000585658
Sc_paper_#2	0,425428185	0,034377717	0,00342926		0,116625441	0,137864191	0,031280684	0,034834557
Ch_screen_#1	0,042993318	0,648520899	0,327711229	0,116625441		0,837103499	0,652370173	0,003910349
Ch_screen_#2	0,021275651	0,518123248	0,20841989	0,137864191	0,837103499		0,500084094	0,001031645
Ch_paper_#1	0,009387799	0,794820213	0,365357348	0,031280684	0,652370173	0,500084094		0,002191026
Ch_paper_#2	0,082435577	0,001913056	0,000585658	0,034834557	0,003910349	0,001031645	0,002191026	

As for Figure 1, it depicts the differences in reading times of the scientific text on screen between two columns and one column. The results show that it is faster, thus more efficient, to read scientific texts in two columns. The results prove, respectively, that the children's text on paper in one column and the scientific text on screen in two columns

promote a faster reading speed, meaning that the reading process is facilitated when presented with these characteristics. In addition to this, the differences of the heart rate variability were studied with regards to these two separate situations.

The minimum, maximum and average values of heart rate activity are shown in Figure 2 e Figure 3 and Figure 4, respectively. Although the differences may seem minimal, it is visible that the heartbeat is slightly lesser when the text is is read in two columns.

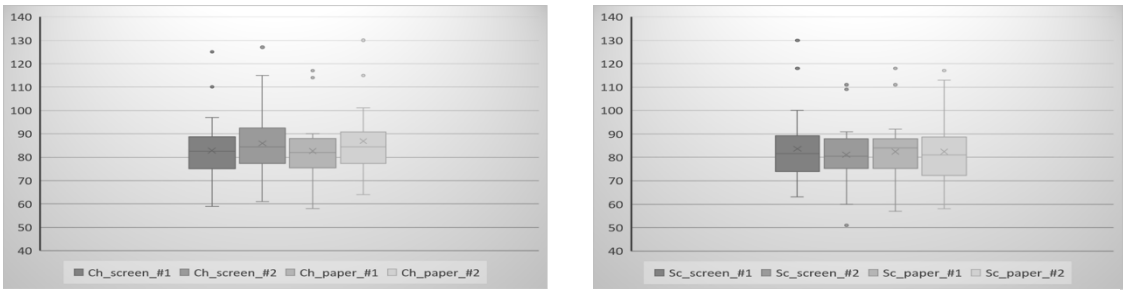

Figure 2 Minimum values of Heart Rate Activity of Children Text (left graphic) and Scientific Text (right graphic), in paper and in screen considering one and two columns

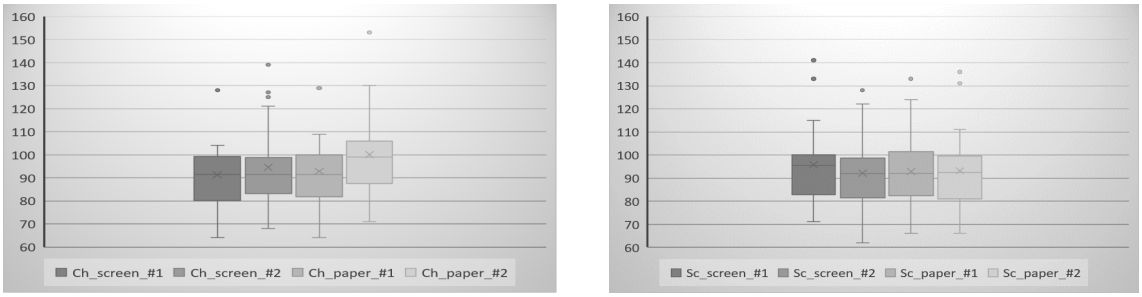

Figure 3 Maximum values of Heart Rate Activity of Children Text (left graphic) and Scientific Text (right graphic), in paper and in screen considering one and two columns

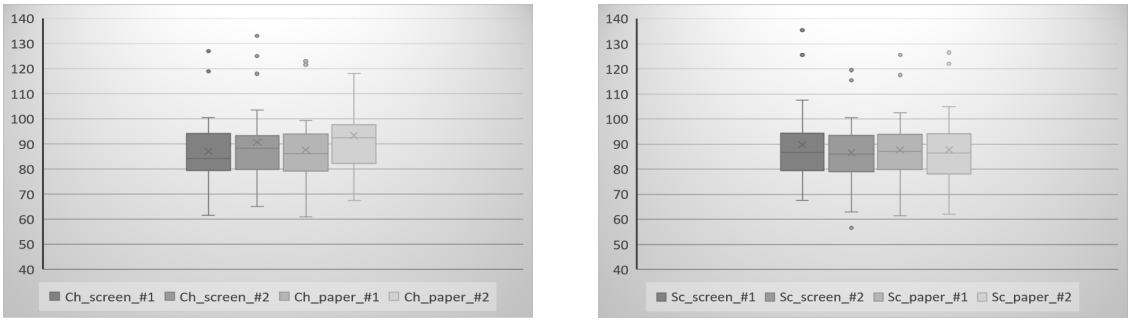

Figure 4 Average values of Heart Rate Activity of Children Text (left graphic) and Scientific Text (right graphic), in paper and in screen considering one and two columns

The table 2, show the statistically comparison of the results (Figure 2, 3 and 4). Significative differences were found.

Table 2 Statistically comparison of HRA average Children Text and Scientific Text, in paper and in screen considering one and two columns

	Sc_screen_#1	Sc_screen_#2	Sc_paper_#1	Sc_paper_#2	Ch_screen_#1	Ch_screen_#2	Ch_paper_#1	Ch_paper_#2
Sc_screen_#1		0,010690911	0,104535992	0,015486506	0,018714425	0,481909279	0,067914404	0,000577538
Sc_screen_#2	0,010690911		0,149094861	0,224558411	0,628066392	0,004102077	0,135644476	1,08697E-05
Sc_paper_#1	0,104535992	0,149094861		0,905811647	0,467109449	0,046313155	0,914769748	0,000699953
Sc_paper_#2	0,015486506	0,224558411	0,905811647		0,429100607	0,042111772	0,960195831	8,87753E-05
Ch_screen_#1	0,018714425	0,628066392	0,467109449	0,429100607		0,024905481	0,446712265	0,000350377
Ch_screen_#2	0,481909279	0,004102077	0,046313155	0,042111772	0,024905481		0,044886862	0,058243225
Ch_paper_#1	0,067914404	0,135644476	0,914769748	0,960195831	0,446712265	0,044886862		0,000257332
Ch_paper_#2	0,000577538	1,08697E-05	0,000699953	8,87753E-05	0,000350377	0,058243225	0,000257332	

The calmness levels recorded by muse device are presented in figure 5. The results of statistical analysis are present in the table 3

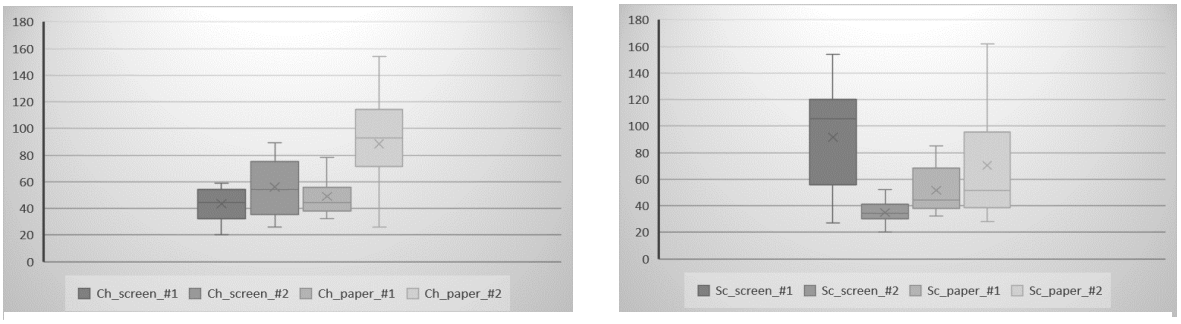

Figure 5 Calmness levels of Children Text (left graphic) and Scientific Text (right graphic), in paper and in screen considering one and two columns

Table 3 Statistically comparison of Calmness level Children Text and Scientific Text, in paper and in screen considering one and two columns

	Sc_screen_#1	Sc_screen_#2	Sc_paper_#1	Sc_paper_#2	Ch_screen_#1	Ch_screen_#2	Ch_paper_#1	Ch_paper_#2
Sc_screen_#1		0,000113793	0,013809655	0,07495654	0,001029919	0,001887299	0,003998933	0,596204375
Sc_screen_#2	0,000113793		0,003619204	0,006918351	0,017895236	0,002675932	0,010200015	4,69445E-05
Sc_paper_#1	0,013809655	0,003619204		0,244642911	0,12614868	0,794093068	0,599731902	0,009793348
Sc_paper_#2	0,07495654	0,006918351	0,244642911		0,064487576	0,350970545	0,201167131	0,063347388
Ch_screen_#1	0,001029919	0,017895236	0,12614868	0,064487576		0,041528055	0,193742226	0,000679265
Ch_screen_#2	0,001887299	0,002675932	0,794093068	0,350970545	0,041528055		0,473116063	0,001214305
Ch_paper_#1	0,003998933	0,010200015	0,599731902	0,201167131	0,193742226	0,473116063		0,001964416
Ch_paper_#2	0,596204375	4,69445E-05	0,009793348	0,063347388	0,000679265	0,001214305	0,001964416	

4. Discussion and Conclusion

The aim of this work is to understand the impact of typography on humans in terms of reading. To achieve the purposed purposed objective of understanding the participants' preferences as a result of a more precise reading process, various tests tests were performed to guarantee the intended outcome. It was verified that in scientific texts is preferable to read in two two columns in digital format (screen) because the reading time is reduced, however this does not mean that facilitates comprehension. The same does not apply to children's reading, which is always preferable in one column. However, reading on paper, on the other hand, is found to be more beneficial when the text has only one column.

The participants also showed a reduction in their heart rate in both situations resulting in positive feedback with regards to the same experiences. Thus, concluding that the preference for reading in two columns is a better choice since there seems to be a false sensation of the reading time passing by faster. Not only did this study corroborate with previous investigations regarding the visual programming of texts, but its results also agreed with them when emphasizing the fact that scientific texts should be read in two columns because it is considered advantageous for the reader to proceed more effectively with the reading process when presented with this type of reading format [20], [21].

The study also proves that reading in (two) columns provides a more readable text flow allowing the individual to read a scientific article from beginning to end with limited fatigue. It allows to navigate between the information in an easy and fast manner being able to look for references that are present in any of the areas of the written content. As a result of these findings, we would like to assume that this study might serve for new and future research of typographic perceptibility and the legibility of text line length.

This study showed that on screen reading speed was significantly faster for two-column scientific texts than for single-column texts, which corroborates previous studies showing that longer line lengths result in longer reading times[26]. However, there is controversy in the literature regarding the comparison of reading times, that some authors pointed longer reading times for the paper [27], [28] and other, longer reading times for screen [29], [30]. Whereas texts with very long and very short lines increase reading difficulty [31] we cannot neglect the participant's reading ability which may act as an important factor for differences in reading speed, since fast readers change their reading strategies based on the current reading goal, but slow readers do not change strategies quickly or easily [2], [32]. Although the reading process can be examined in many ways, there are two most used in comparing text reading from screens and role that are reading time and metacognitive accuracy. Reading time is a pro-process measure where longer read times are considered indicative of more throughput and increased effort [27], [33]. Given these issues, it is not surprising that some argue that reading from screens may only be suitable for easy light reading [34] and reading time is longer from screens than paper, but without any relative benefit to comprehension [5], [12], and there is screen inferiority, in which readers have weaker performance and metacognitive awareness of their performance, on assessments based on reading from screens compared to paper [33] . However, although no method is better than the other for understanding the information presented and depending on the purpose previously defined for each reading behaviors [21], the experience of reading from screens is frequently described as less pleasant and less engaging than that of reading from paper [28].

Readers may demonstrate better performance in the single-column condition, as very short lines may impede the slow reader's ability to absorb an optimal amount of information in each fixation [27], [35], as some studies suggest that slow readers read word by word [24], hypothesizing that shorter lines allow for more clustering and less stress on short-term memory load [36], [37]. Another important issue is the type of the texts (narrative and expositive texts) because they are differently constructed, with narrative texts generally being easier to read than expositive texts [38] and understanding performance is generally better for narrative than expository texts [33], [39]. One study which participants reading a science book revealed a 28% faster reading time in a three-column condition than reading the same passage with only one column, however, no differences was found in comprehension or preference for either condition, despite participants reporting that the three-column display them shorter than the single-column format [40]. More recently, a study using eye tracking showed that subject's comprehension was better when reading on paper. Eye movement data indicated that the print and digital groups spent approximately the same amount of time processing the article, but the time was not equally divided between the first pass and the rereading stages. The digital group spent more time reading the article in the initial reading stage and rarely reread it, in contrast to the paper reading group who first skimmed the article and then reread the parts deemed most

important, exhibiting longer total fixation durations in the rereading stage and a greater number of instances of rereading across pages. In sum, we could say that the results of this study appear to reveal that reading in print versus digital media employs different cognitive strategies, with reading in print media showing more selective and intentional reading behaviors [40], [41]. Automating visual word choice through recognition is also important for readers, as non-automated or laborious word recognition occupies attention resources that may be more useful for higher-level comprehension and memory storage[28], [42]. Adults are also known to achieve levels of automated word recognition, and this assumption is a standard view of cognitive research, since the tendency to read words is not easily eliminated with practice [43] and there is a benefit for reading comprehension when reading from paper compared to screen [44]. It should be noted that effective metacognition and meta comprehension process strategies are needed to ensure reading comprehension[36], [45], which could include mental strategies and manipulations of texts, words, sentences, paragraphs, or whole-text level to enhance reading comprehension [40].

In this study we concluded that the reading time presents the same performance obtained by EEG and ECG sensors. Thus, we concluded that a shorter reading time increases the level of calmness and reduces the average heart rate (HRA). On the other hand, longer reading times lead to lower levels of calmness and a faster heart rate activity. With this study we also concluded that the use of sensors is discriminative to understand the performance of the user and the user engagement in reading two types of texts considering two different platforms (screen and paper). Furthermore, the number of errors during the experiment, corroborate the conclusions previously presented.

Although our study is very limited, considering the variables and sample size used, we conclude that there is a need for further studies for understanding the predictors of findings comparing reading from paper and screens, and longitudinal studies to deepen the importance of these important variables, namely regarding the cognitive strategies used by the participants and for the measurement of their comprehension, attentional levels, and short and long-term memory.

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