Proceedings of the 9th World Congress on Electrical Engineering and Computer Systems and Sciences (EECSS'23)
Brunel University, London, United Kingdom - August 03-05, 2023
Paper No. MHCI 110
DOI: 10.11159/mhci23.110

Behavioral Differences and Impact of Lowercase and Uppercase Letters on Reading Performance

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Abstract **-** The aim of this work is to understand the impact of lowercase letters and uppercase letters in terms of reading. Four sessions were held in which subjects are aged from 15 to 59 years old. Of the 19 participants with a mean age of 26.52 years (SD=13.14), to understand which letters (lowercase versus uppercase) presents a shorter reading time and higher levels of calmness, considering two different complexity texts (children and scientific) in two different forms of interaction (paper reading and screen reading). Several tests were carried out to ensure the intended result in order to comprehend the influence of various visual variables because of a more precise reading process. Four variables were examined using various sensors, including the Brain Computer Interaction (BCI) device, to measure heart rate activity (HRA) and levels of brain activity (active, neutral, and calm). The number of errors, the reading time, the heart rate variability and the calmness, active and neutral levels were considered. Our findings demonstrate that depending on the type of letters (lowercase versus uppercase), and the type of text (scientific versus children's text), and the reading text presentation (paper or screen), the visual variables have a different effect on reading performance.

Keywords**:** HCI; Interaction Design; Visual Variables; Typography; BCI

1. Introduction

The typographer has the role of identifying and working the visual characteristics of a letter. To draw upper and lowercase letters, various shapes, lines, and dots are used. These are designated body, legs, feet, arm, eye, tail, among others. These characteristics of the letters show differentiating the lowercase letters and uppercase letters,

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) [1]. In this sense, there are some evidences from the fields of typography and cognitive science that lowercase text is more readable [2], [3]. The word's shape is more perceived in upper and lower case than only having uppercase, something that results from the course of all capital characters having the same height and have no ascending and descending, while the lowercase characters, which have ascending and descending, vary both in height and position [1]–[3].

Considering the phenomenon "word superiority effect" [4] postulates that there is greater accuracy in word recognition than in letters, and shows the dominance of word shape in word recognition, in relation to letter recognition, considering that lowercase words have shapes more distinct than uppercase letters, fuelling the belief that the effect of word superiority is largely responsible for the better legibility of lowercase text [2], [5].

Although the speed of reading lowercase letters and uppercase letters be emphasized, usually reading texts written in uppercase letters is more difficult than the reading of texts written in lowercase letters, and there is a need to avoid the use of uppercase letters in a full text [6]. According to the same authors the uppercase is very similar to each other and that for this reason, the uppercase increases the confusion and slow down the reading. It also argues that texts written in uppercase have a deficiency of rhythm and slowness, and that lowercase facilitate recall and therefore even words in lowercase are easily placed in the mental dictionary due to their advantage of visual recognition.

In terms of shape variation and the contrast of ascenders and descenders with short letters, lowercase letters have more "character." This leads to characteristic word forms that are much easier to recognize than words in all capitals. This is true even though capital letters are simply more visible than lowercase ones [1], [7], since every word written in uppercase letters takes the form of a horizontal rectangle (e.g., CAT, DOG, PIG), uppercase letters do not create word shapes [8].

A recent study with 732 participants demonstrated that the reading speed of text written with lowercase letters is greater than the reading speed of text written with uppercase letters [6]. Considering to various behavioural experiences [9] also confirms that the words displayed in lowercase produce word recognition times faster than the words presented in uppercase.

Also, visual variables have a crucial role in understanding reading performance and its significance in the history and contemporary practice of typography. Some authors investigate how visual factors affect readability, including how letters and words are perceived and how continuously reading text is read [10], [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].

In a recent study the authors highlighted the importance of low-level visual factors, corroborating the emphasis of recent psychological models on visual attention and crowding in reading, [12]. Some authors used sensors to evaluate the typography [13] 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 also for the comprehension of participants for 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 [16], [17]. 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) [18].

In this sense, typographers and cognitive researchers have made considerable progress in identifying and working on the visual characteristics of a word, however there are still many questions about visual word identification: the effects of the letter case during word recognition.

Nonetheless, this research aimed to understand the different readings and the aspects associated with them (lowercase letters and uppercase letters; paper or digital; 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 experiment, 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, speed reading, heart rate and brain activity. Both young adults (university students) and children (middle-school students) were recruited. Both age groups included typical readers on paper and on screen, to address potential modulations of the effects of visuo-typographic factors as a function of type of text as well as reading medium.

This paper is organized as follows: First, the introduction of the problem is done; second, the methods (participants, procedures, methodology 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 are aged from 15 to 59 years old. Of the 19 participants with a mean age of 26.52 years (SD=11.52) with varying levels of education starting at the fourth grade to a doctorate's degree as well as possessing diverse professional backgrounds.

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

These tests took three weeks to be fully conclude. The procedure started off by handing out forms, where the participants would fill their personal information, regarding their age, gender, profession, schooling year, their reading habits, habits, what type of reading they preferred the most (or paper or screen) and if they wore glasses. To make the text reading reading possible, we requested the use of an empty classroom. Once the equipment's were prepared, participants were called called one by one, seat and strapped to devices that collected and stored information about their cerebral and cardiac activity.

While the participants were reading, a video were being recorded, so they could be analysed later and to produce a stricter form and on detail the test results. Each test took around three minutes. The number of errors, the time reading and the parameters extracted by the two devices such as, Heart Rate Variability, Calmness level , Active level and Neutral level will be analysed in this study.

2.2. Methodology

The experiment was designed to explore the preferences of participants regarding the type and format of their favourite reading material. The experiment appears to have used two variables: the type of text (scientific vs children's) and the text presentation (paper vs screen) considering lowercase and uppercase letters.

The primary objective of the study appears to be to determine which types and formats of reading materials are most popular among the participants and to understand the reasons for their preferences. To achieve this objective, the experiment likely collected data from the participants, which was then analysed to identify any patterns or trends in their reading preferences. Additionally, the experiment may have also assessed the participants comprehension of the selected reading materials to gain further insights into the reasons for their preferences.

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:

- Children text in Upper case on screen: UP_Ch_screen
- Scientific text in Upper case on screen: Up_Sc_screen
- Children text in Upper case on paper: UP_Ch_paper
- Scientific text in Upper case on paper: UP_Sc_paper
- Children text in Lower case on Screen: Low_Ch_screen
- Scientific text in Lower case on Screen: Low_Sc_screen
- Children text in Lower case on paper: Low_Ch_paper
- Scientific text in Lower case on paper: Low_Sc_paper

2.3. Devices

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

Muse is a Brain Sensing Headband [19], 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 [20]. 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 is only possible to detect through the 7 brain sensors EEG (electrical braingraph) if they are calibrated: 2 in the forehead, 2 behind the ears and 3 reference sensors - that detect and measure the activity of the brain.

The Polar Smart Watch [21] 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 [21], [22].

3. Results

The analysis was made considering different parameters. The Muse parameters, the Polar Smart Watch parameters, the time reading, and the number of errors were analysed.

Figure 1 provides information of the number of errors made by participants during the reading of the eight different texts. The Figure shows that the scientific text in lowercase letters, whether it was presented on screen or paper, resulted in the highest number of errors, followed by the scientific text in uppercase letters on screen.

On the other hand, the children's text in both lowercase and uppercase letters resulted in the lowest number of errors for all presentation methods, indicating that it was the easiest text for participants to read and comprehend.

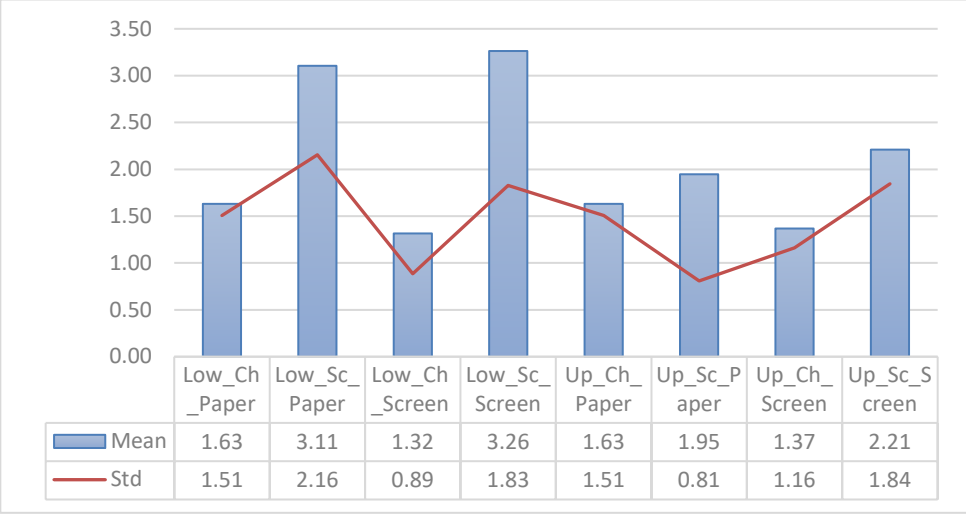
These results suggest that the complexity and vocabulary of the text have a significant impact on the participants ability to read and comprehend the text, and that letter case and presentation format may also play a role in reading performance.

Based on the information provided by Figure 1, it appears that the experiment has identified some key insights into the participants reading habits and preferences. One finding is that participants made more errors when reading scientific texts, regardless of whether they were reading them in print or digital form in lowercase letters.

It is possible that the use of lowercase letters in scientific texts may have contributed to the higher number of errors observed in the participants reading. It is well-established that uppercase letters are generally easier to read and recognize than lowercase letters, as they have a simpler and more distinct shape.

The finding that scientific texts caused more errors than other types of texts is not surprising, as these texts are often more complex and technical in nature, which can make them more challenging for readers. However, the use of lowercase letters may have further compounded this difficulty, making the texts even harder to read and comprehend.

It is also worth noting that the study found no significant difference in the number of errors made by participants when reading print versus digital texts. This suggests that the format of the text does not have a significant impact on the participants ability to comprehend it, at least in terms of the number of errors made.



	Low_Ch_Paper	Low_Sc_Paper	Low_Ch_Screen	Low_Sc_Screen	Up_Ch_Paper	Up_Sc_Paper	Up_Ch_Screen	Up_Sc_Screen
Mean	1.63	3.11	1.32	3.26	1.63	1.95	1.37	2.21
Std	1.51	2.16	0.89	1.83	1.51	0.81	1.16	1.84

Figure 1 Number of errors considering Lowercase and Uppercase

Looking at the reading time graphs, in lowercase, the scientific text on screen took the most time, however in uppercase the highest time of reading was the scientific text on paper, Figure 2.
It is interesting to note that the reading time graphs showed different patterns depending on the type of text and the letter case used. For instance, in the case of lowercase letters, the scientific text on screen took the most time for participants to read, while in the case of uppercase letters, the scientific text on paper took the most time.

This finding may suggest that the factors that influence reading time can vary depending on the specific characteristics characteristics of the text, such as its complexity, vocabulary, and formatting. It is also possible that the reading environment or the participants individual reading skills may have played a role in these differences.

Making a statistical analysis between uppercase and lower case, we see that the reading time between uppercase and lower case is statistically different considering Sc_Paper ($p=0.0629$); Ch_Screen ($p=0.0027$) and Sc_Screen ($p=0.0014$).

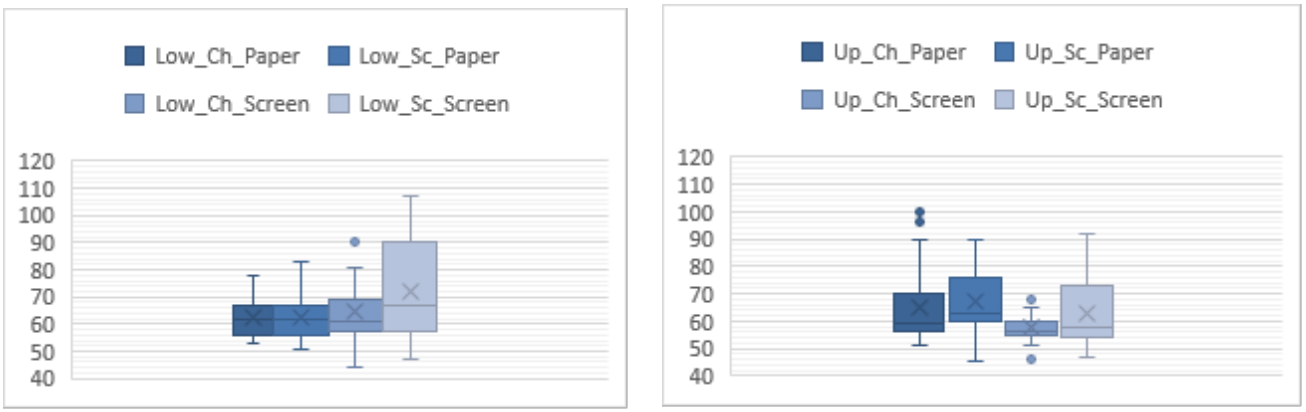


Figure 2 Reading Time considering Lowercase letters (left) and Uppercase Letters (right).

The Heart Rate variability is also analysed, and the results are presented in Figure 3. The comparison of heart rate and reading time is an interesting aspect of the experiment, as it provides insight into the participants physiological response to reading different types of texts.

The finding that participants had a lower heart rate and shorter reading times when reading texts in uppercase letters suggests that this format may be more comfortable and accessible for readers. This may be because the larger and more distinct in uppercase letters are easier to read and comprehend, which can reduce cognitive load and improve reading efficiency.

These results support the notion that letter case can have an impact on reading performance, and that uppercase letters may be a more optimal choice for readers who struggle with reading or have lower levels of literacy. However, it is worth noting that other factors, such as the complexity of the text and the individual characteristics of the readers, may also play a role in determining the most comfortable and accessible reading format.

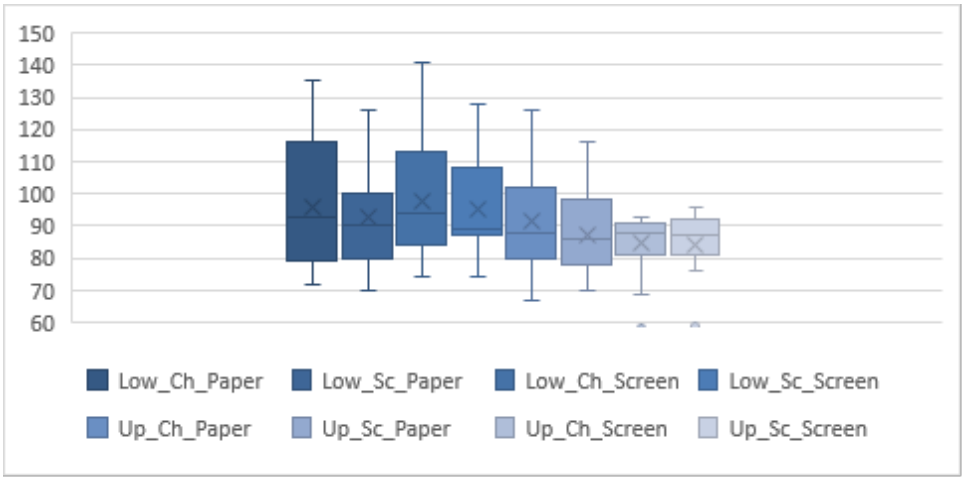


Figure 3 Heart Rate Variability

Table 1 presents the mean and standard deviation of the active, neutral, and calm levels extracted by a Muse device. The table shows that the level of calmness was higher when participants read texts presented in lowercase letters, indicating that this presentation format may have a calming effect on readers.

However, the table does not show a distinctive value for the levels of neutral or active. This suggests that the presentation format (i.e., lowercase or uppercase letters) may not have a significant impact on the levels of neutral or active in the participants, as these levels remained relatively consistent across all presentation methods.

To better understand the calmness level parameter, the Figure 4 represent all the values of calmeness level considering all the participnats. As we can see, a hight variability is found in lowercase letters. The statiscally analysis will be done to better understand if the differeneces are satistically significants.

Comparing the lowercase letters with uppercase letters we found that in case of scientific text in paper and children text in screen the results are statiscally different with ($p=0.046$) and ($p=0.018$) , respectively.

These statistical results suggest that there is a significant difference in the use of lowercase and uppercase letters between scientific text in paper and children's text on screen considering the calmness level.

In the oher hand, others differences were founded in Lowcase letters experiements: Low_Ch_Paper and Low_Sc_Paper ($p=0.02$); Low_Ch_Screen and Low_Sc_Screen ($p=0.001$); Low_Ch_Paper and Low_Ch_Screen ($p= 0.015$).

In the case of uppercases letters experiments, no differences were founded.

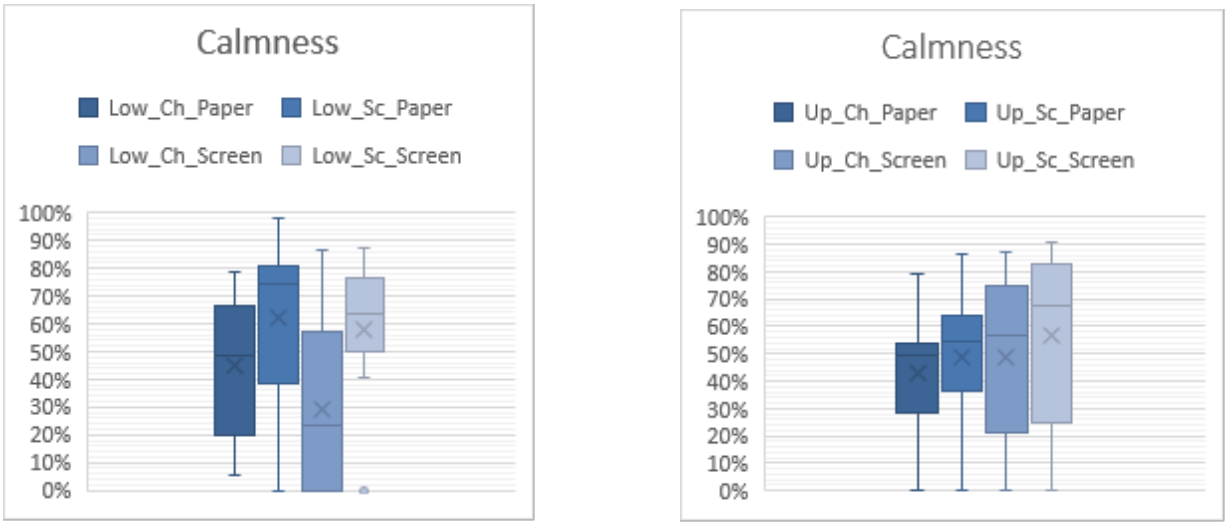


Figure 4 Calmness level – Considering Lowercase (left graphic) and Uppercase (right graphic) letters.

Table 1. Mean and Standard deviation of active, neutral, and calm levels considering the study.

	Low_Ch_Paper			Low_Sc_Paper			Low_Ch_Screen			Low_Sc_Screen		
	Ative	Neutral	Calm	Ative	Neutral	Calm	Ative	Neutral	Calm	Ative	Neutral	Calm
Mean	9%	46%	45%	11%	27%	62%	23%	48%	29%	6%	36%	58%
SD	12%	18%	21%	12%	16%	27%	17%	21%	25%	6%	14%	17%

	Up_Ch_Paper			Up_Sc_Paper			Up_Ch_Screen			Up_Sc_Screen		
	Ative	Neutral	Calm	Ative	Neutral	Calm	Ative	Neutral	Calm	Ative	Neutral	Calm
Mean	10%	32%	33%	12%	21%	44%	20%	34%	27%	6%	25%	38%
SD	1%	14%	12%	1%	6%	17%	3%	14%	2%	0%	11%	20%

5. Discussions and Conclusions

The aim of this work is to understand the impact of uppercase and lowercase letters in terms of reading considering various parameters. To achieve the purposed objective of understanding the participants preferences because of a more precise reading process, various tests were performed to guarantee the intended outcome.

The number of errors, the reading time, the heart rate variability and the calmness, active and neutral levels were considered. The findings demonstrate that depending on the type of letters (lowercase versus uppercase), and the type of text (scientific versus children's text), and text presentation (paper or screen), the visual variables have a different effect.

Our results shows that the scientific text in lowercase letters, whether it was presented on screen or paper, resulted in the highest number of errors, followed by the scientific text in uppercase letters on screen, which corroborates previous investigations regarding the visual programming of texts, but this results also agreed with them when emphasizing the fact that lowercases is considered advantageous for the reader to proceed more effectively with the reading process when presented with this type of reading format [23], [24].

Looking at the reading time, in lowercase, the scientific text on screen took the most time, however in uppercase the highest time of reading was the scientific text on paper. It is interesting to note that the reading time showed different patterns depending on the type of text and the letter case used. For instance, in the case of lowercase letters, the scientific text on screen took the most time for participants to read, while in the case of uppercase letters, the scientific text on paper took the most time.

Our results contradicts a recent study which confirms that the reading speed of text written with lowercase letters is greater than the reading speed of text written with uppercase letters [6], however our study demonstrated that the level of calmness was higher when participants read texts presented in lowercase letters, indicating that this presentation format may have a calming effect on readers, which allows us to agree with the previous studies, and also considering to various behavioural experiences [2], [9] which also confirms that the words displayed in lowercase produce word recognition times faster than the words presented in uppercase .

Its important to higlight that the main goal of our study analysed, different text (children vs scientific) and different texts presentation (screen vs paper). Those factors may influence reading time and depending on the specific characteristics of the text, such as its complexity, vocabulary, and formatting. Also, the reading environment and individual reading skills may have influence in those differences.

Our finding also demontrated that participants had a lower heart rate and shorter reading times when reading texts in uppercase and suggests that this format may be more comfortable and accessible for readers. This may be because the larger and more distinct in uppercase letters are easier to read and comprehend, which can reduce cognitive load and improve reading efficiency. This can lead to reduced comprehension and difficulty in concentrating, furthermore, reading on a screen can also cause physical and mental fatigue due to the strain of staring at a digital device for an extended period [17], [25].

It is important to note that the interpretation of these results may be limited by a variety of factors, such as the sample size and the specific texts used in the experiment. Further analysis and replication studies may be needed to fully understand the impact of letter case on readers' levels of calmness, as well as the levels of neutral and active.

Acknowledgements

We thank students Ana Castro, Beatriz Monteiro, Hugo Oliveira, and Rafael Conceição for their support in collecting data for this work.

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