COLOURED OVERLAYS IMPROVE READING PERFORMANCE IN PEOPLE SUFFERING FROM VISUAL STRESS

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ABSTRACT

The ability to read fast and effortless, with good comprehension, is nowadays essential for an independent and successful academic, professional and social life. However, many people feel discomfort and see distortions when reading. This condition, called visual stress, is possibly a consequence of a visual cortex hyperexcitability due to the occurrence of stripped pattern on texts. Several studies have shown that the use over texts of transparent colored plastic sheets, known as overlays, significantly improve some reading-related parameters, and so, enhance reading fluency on an adult population. These overlays work through the absorption of part of the visible spectrum, less exposing and less stimulating the eye receptors sensitive to this specific region. The use of a customized overlays decreases visual stress and increases visual comfort, extending periods of reading and enabling decoding techniques and other reading strategies to be applied. The investigation of oculomotor and other reading related parameters can help in the analysis of the visual process during reading. This study aimed to analyze the number of fixations, the number of regressions, the span of recognition, the average duration of fixation, the number of words read per minute, the cross correlation and the comprehension rate of 62 adults suffering visual stress and with indication for coloured overlay intervention. All participants had normal uncorrected or corrected visual acuity and were free of eye or neurological diseases, other than the visual stress related. Participant's reading performances were measured by Visagraph System when reading within and without a personalized spectral overlay. Statistical analysis showed significant ($p<.05$) improvement between five of the seven analyzed reading parameters within overlay use in people suffering from visual stress, suggesting the effectiveness of spectral intervention in the improvement of reading performance in this population.

Keywords: reading, visual stress, coloured overlays, eye-tracking, spectral intervention

A. BACKGROUND

In everyday life, there are many usual activities that may cause discomfort, such as working with texts [1,2]. The exposure to bright or flickering lights and to certain visual repetitive striped patterns with spatial frequencies between 1 and 4 cycles/deg., like single-spaced text pages, may be a trigger for visual stress in some people [2,3,4,5]. Kriss and Evans (2005) [6] describe visual stress as the inability to see comfortably without distortion. Some symptoms can be eyestrain, headache and illusions of color, shape and motion [7].

Reading is a complex activity involving human vision that is important for an independent life nowadays [9,10]. The physical stimulus that triggers the human visual process is the light in the range from 380 nm to 760 nm. In the eye, this light energy acts on the retinal photoreceptors, being transformed into neural impulses that transmit sensory information to the brain areas responsible for visual processing [11]. To read, it is in the cortical areas that the letter recognition, the transcription in language and the meaning assignment take place [12].

In order to read in an effective way, the eyes need to move efficiently along the line of printing. The correct accomplishment of the saccade series intercalated with fixations and with some regressions make up the pattern of eye movements [11,12]. These movements require the ability to accurately coordinate the extra-ocular muscle activity in cooperation with visual sensory functions [13].

It was found that symptoms of visual stress during reading can be alleviated by use of spectral or coloured overlays, placed over printed texts [17], and by use of selective blocking spectral lenses [18,19,20]; the latter being more effective and recommended for long-term use [21,22]. The optimal block-range for lenses is not exactly the same as for sheets [23], and it can be selected with far greater precision.

Spectral or coloured overlays are transparent colored plastic sheets that can be placed over printed texts. They absorb part of the visible spectrum, and so, less expose and less stimulate the eye receptors sensitive to this region. A coloured overlay needs to be of a size sufficient to cover the text, but it does not have to cover the surrounding area [24]. The use of an specific individually selected overlay decreases visual stress and increases visual comfort, extending periods of reading and enabling decoding techniques and other reading strategies to be applied. Although a decrease in visual stress appears to improve visual processing, it does not teach reading skills [25] and academic tutoring is still required as most of this population are disabled readers.

Nowadays, it is widely recognized that spectral filters of a precisely selected block-range are able to reduce the distortions seen in text and to increase reading speed [5,17,26,27,28,29]. Two rigorous double-masked randomized placebo controlled trials [22,30] validated the management of visual stress with individually prescribed colored filters. These studies demonstrated that coloured overlays use reduces symptoms of headache and eyestrain and increases reading accuracy and comprehension. Both trials identify the benefit from colored overlays as idiosyncratic and specific: different colors, defined with some degree of precision, are needed for different people. This statement is supported by some single masked clinical trials [5,6,27,31,32,33,34]. The beneficial outcome of coloured overlays use is not due to a placebo effect [28,31,35]. Also, the preference for a specific overlay is not related to familiarity, memory [36] or a reduction in contrast [26].

The oculomotor pattern displayed during a reading task is considered a demonstration of the fundamentals of an individual reading process [37]. Therefore, its investigation associated with the investigation of others reading related parameters can help in the analysis of the oculomotor performance and the visual process during reading.

B. RELEVANCE FOR THE FIELD

Reading failures can be related to dysfunctions of the visual system, especially to disfunctions of the oculomotricity [9,14,15]. Furthermore, they can also be associated with the induction of visual stress by parallel lines, paragraphs and some words like “mum”, which can be conceptualized as striped patterns [2,8]. Visual stress can negatively affect the ability to read for long periods [16].

The use of coloured overlays has been shown to reduce visual stress and to enhance reading ability in adults suffering from this condition. Some of the improvements on reading-related parameters seen with the use of overlays are a decrease in the number of fixations and regressions, an increase in the span of recognition and an increase in the number of words read per minute.

C. MAIN OBJECTIVES

Given the importance of reading disorders, the aim of this study is to investigate the effect of intervention with color-personalized overlays on reading performance of adults suffering visual stress.

D. METHODOLOGY

- Participants:

Participated in the study 62 adults (38 males and 24 females), aged 18 to 57 years (mean=30.4, standard deviation=10.4), with visual stress (increased light sensitivity, eye pain, physical discomfort and headache), reading problems (sluggishness and fatigue, skip letters or words, lose place, need for reread, reduced reading time tolerance, avoidance of reading, and struggle for understanding) and indication for spectral filters therapy. All participants had normal or corrected visual acuity and were free of eye or neurological diseases, other than the visual stress related.

- Equipment:

In order to measure oculomotor pattern during reading, VisagraphTM III Eye-Movement Recording System [37], was used. It is an eye tracking computerized system which is a useful tool for evaluating reading skill. The system consists of the analysis software that may be installed in any ordinary personal computer; a measuring unit connected to an USB port on the computer and eye tracking goggles without lenses. The goggles contain infrared sensors placed in front of the eyes and centered on each pupil to register eye movements (Figure 1).

Figure 1: VisagraphTM III components: measuring unite, which is connected to a computer with the analysis software (left) and eye tracking goggles (right) [38]

- Procedure:

All participants were tested in two conditions: without (control group/CG) and within (experimental group/EG) the customized coloured overlay. Measurements were performed by VisagraphTM III. It was possible to wear refractive glasses or contact lenses under the eye tracking goggles when needed.

The system recorded micro eye movements performed by each eye during reading aloud a short text on paper. Reading were performed in a seated position with feet on the floor, forearms resting on a table in front of them and holding the text to be read with both hands, in the most comfortable distance, chosen by each participant. For control and experimental conditions, different standardized texts in same difficulty level were used.

The eye movement pattern was automatic analyzed, and a number of quantitative reading parameters are calculated. After reading, the recorded eye movements can be studied as function of time.

As the goggles are attached to the participant's head and, therefore, head movements are compensated (removing the need for alignment of the individuals) and saccades and line shifts are localized. First and last lines of the read text are discarded in calculation, since they can have some irregularities on them. In the rest of the text, fixations, regressions and fixation duration are counted and calculated.

The reading parameters used to measure and analyze reading performance were: 1) Fixations (FIX), number of eye pauses per 100 read words; 2) Regressions (REG), number of significant right-to-left eye movements (backward saccades) per 100 read words; 3) Span of recognition (SPAN), number of read words divided by the number of fixations; 4) Average Duration of Fixation (DUR), total reading time (in seconds) divided by number of fixations; 5) Words per minute (WPM), refers to the reading speed in words per minute; 6) Cross-Correlation (CC), a statistical analysis of the equivalence of horizontal movements of the subject’s eyes through the countable lines of print, indicating the percentage of time that the two eyes work in a synchronized way; 7) Comprehension rate (CR), refers to the percentage of comprehension questions answered correctly after the reader completed the Visagraph test [37].

E. RESULTS (or expected results)

After each test, without and within coloured overlays , the software generated a report containing the results of each volunteer. All variables and their results were plotted in a spreadsheet grouped by condition (without or within spectral filter). The sample size was based on the number of participants' eyes (N≈62x2; N≈124).

For the quantitative analysis of the data (Table 1), mix-design ANOVA were used, with a between effects factor (lack or use of spectral filters) and a within effects factor (measured reading parameters). The ANOVA applied to the oculomotricity data revealed significant difference between groups [$F(7,215)=8.00; p<0.05$], and interaction [$F(7,215)=23.13; p>0.05$].

Table 1 – Descriptive Statistics for Reading-Related Parameters (number of fixation, number of regressions, recognition range, fixation average duration, words per minute, binocular correlation and comprehension rate) from the control group (CG) and the experimental group (EG)

CG	Mean	Min	Max	SD	SE
Fixations	181.09	52.00	428.00	80.75	7.63
Regressions	44.80	4.00	134.00	30.84	2.94
Span of Recognitions	0.57	0.15	1.30	0.26	0.02
Average Duration of Fixation	0.21	0.09	0.36	0.06	0.01
Words per Minute	142.63	71.00	214.00	36.95	3.66
Cross-Correlation	87.78	57.00	100.00	10.62	0.98
Comprehension Rate	86.03	70.00	100.00	10.53	0.95
EG	Mean	Min	Max	SD	SE
Fixations	158.49	51.00	365.00	69.96	6.50
Regressions	38.55	6.00	118.00	27.76	2.62
Span of Recognitions	0.70	0.17	1.52	0.33	0.03
Average Duration of Fixation	0.21	0.10	0.39	0.07	0.01
Words per Minute	181.77	88.00	333.00	61.12	5.78
Cross-Correlation	92.06	79.00	100.00	5.57	0.57
Comprehension Rate	88.69	70.00	100.00	9.96	0.89

[a]Legend: Mean values (Mean), minimum values (Min), maximum values (Max), standard deviations of the mean (SE) and standard errors of the mean (SE).

Fisher LSD post hoc analysis showed significant differences ($p < 0.05$) between CG and EG to all but two reading-related parameters analyzed in this study: fixation (FIX), regressions (REG), span of recognition (SPAN), words per minute (WPM) and cross-correlation (CC). The only non-statistical significant ($p>0.05$)

differences were the average duration of fixation (DUR) and the comprehension rate (CR).

- Fixations (FIX):

FIX during reading reduced ($p<0.05$) from 181.09 ± 80.75 (without overlay) to 158.49 ± 69.96 (with coloured overlay) (Figure 2).

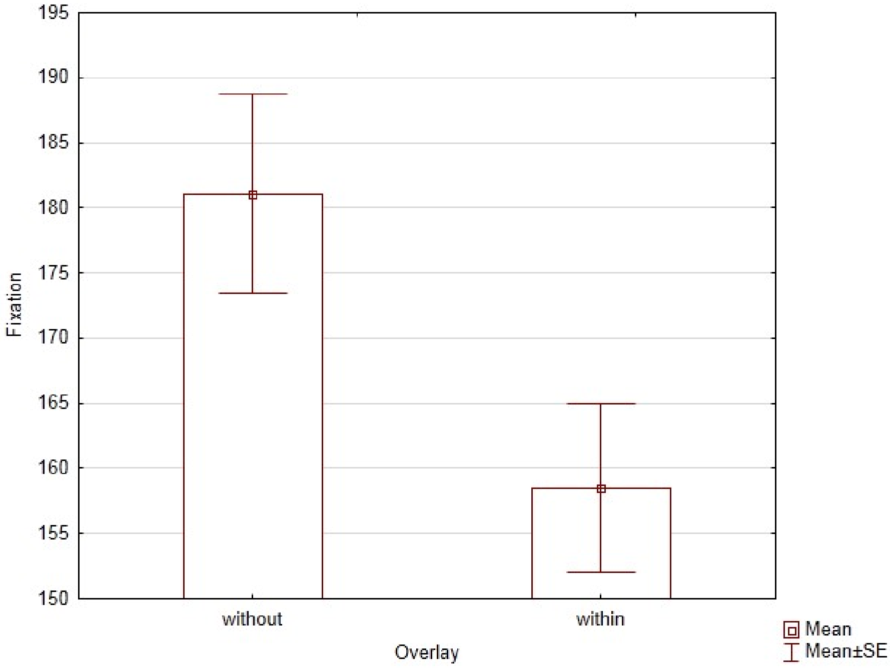

Figure 2: Number of fixations (y-axis) without (CG, N = 112) and within (EG, N = 116) individually prescribed coloured overlay filters (x-axis)

-Regressions (REG):

REG during reading reduced ($p<0.05$) from 44.80 ± 30.84 (without coloured overlay) to 38.55 ± 27.76 (with coloured overlay) (Figure 3).

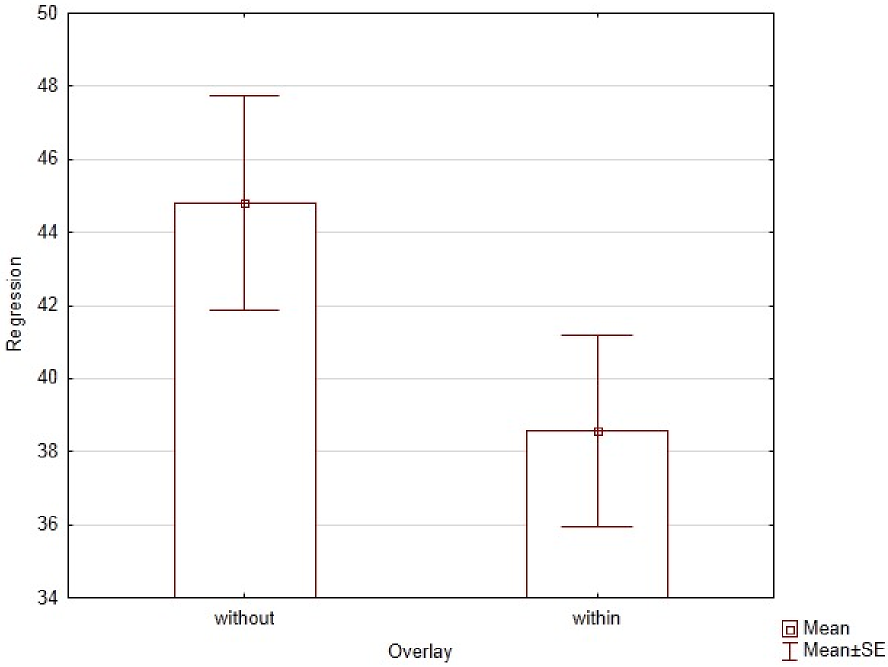

Figure 3: Number of regressions (*y-axis*) without (CG, N = 110) and within (EG, N = 112) individually prescribed coloured overlay (*x-axis*)

- Span of Recognition (SPAN):

SPAN during reading increased ($p<0.05$) from 0.57 ± 0.26 (without coloured overlay) to 0.70 ± 0.33 (with coloured overlay) (Figure 4).

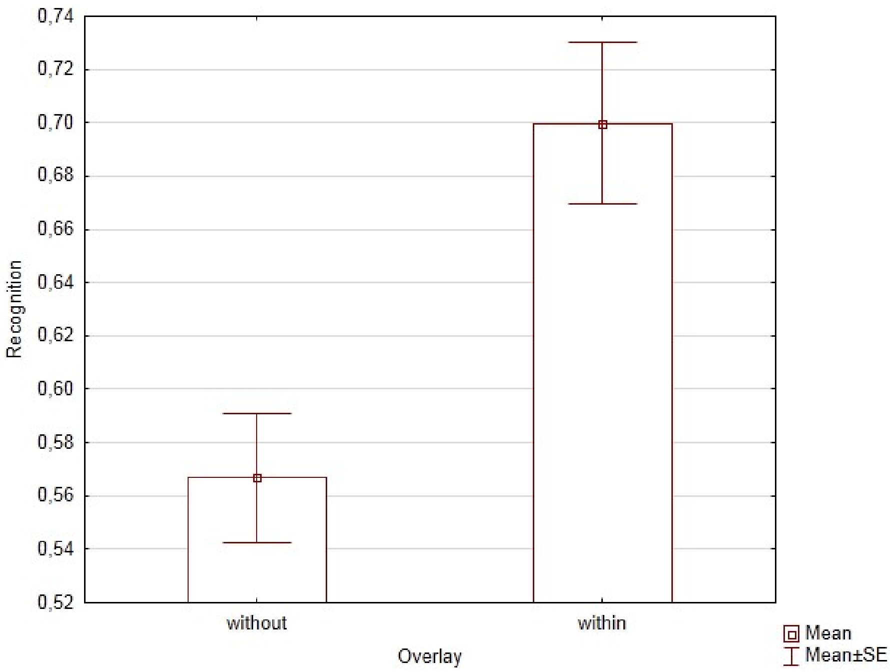

Figure 4: Recognition Range (*y-axis*) without (CG, N = 116) and within (EG, N = 120) individually prescribed coloured overlay (*x-axis*)

- Average Duration of Fixation (DUR):

DUR during reading was 0.21 ± 0.06 when coloured overlay were not used and 0.21 ± 0.07 when they were used ($p>0.05$) (Figure 5).

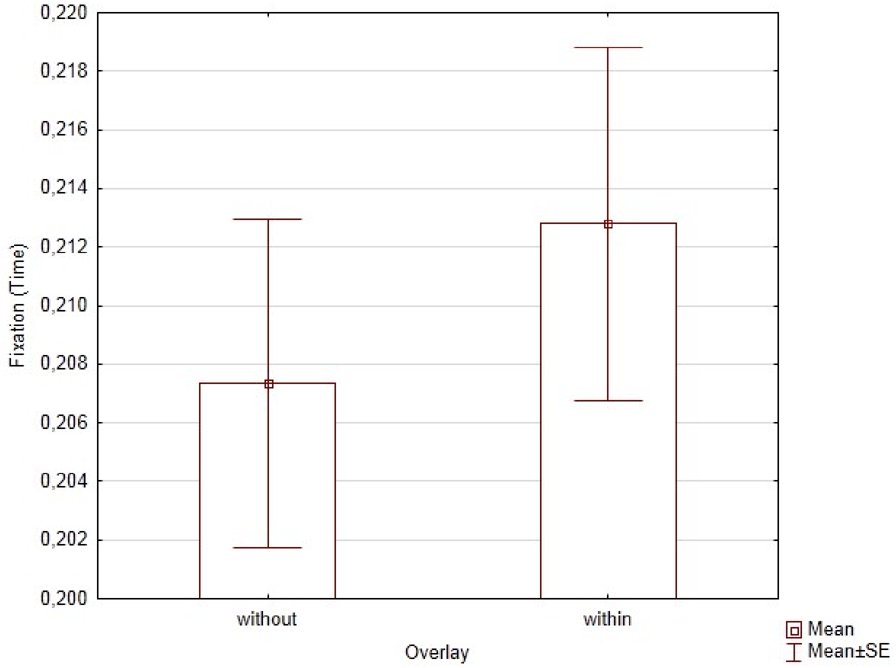

Figure 5: Fixation Average Duration (*y-axis*) without (CG, N = 120) and within (EG, N = 122) individually prescribed coloured overlay (*x-axis*)

- Words per Minute (WPM):

WPM during reading increased ($p<0.05$) from 142.63 ± 36.95 (without coloured overlay) to 181.77 ± 61.12 (with coloured overlay) (Figure 6).

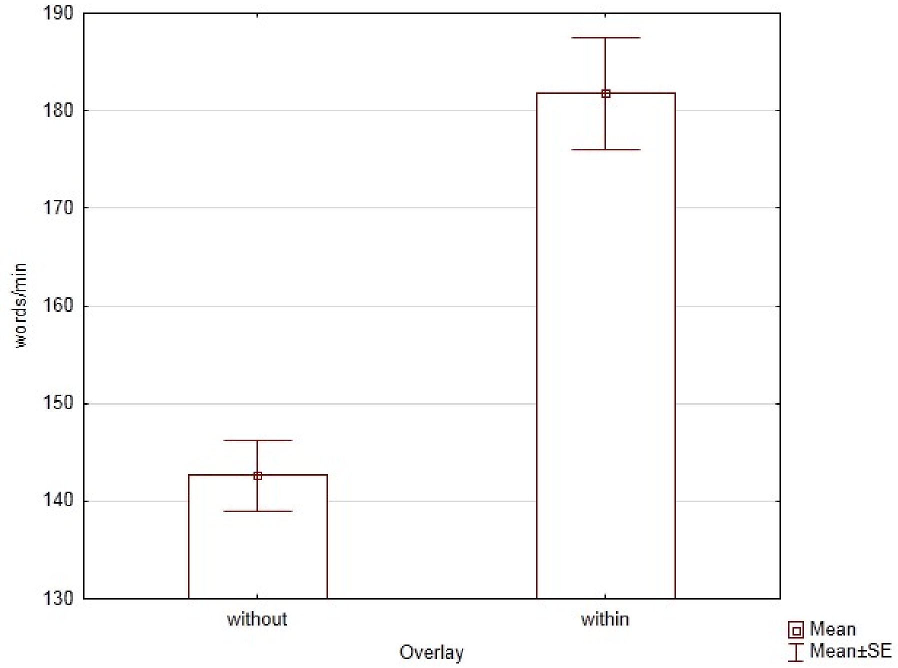

Figure 6: Number of Words Read per Minute (*y-axis*) without (CG, N = 102) and within (EG, N = 112) individually coloured overlay (*x-axis*)

- Cross-Correlation (CC):

CC during reading increased ($p<0.05$) from 87.78 ± 10.62 (without coloured overlay) to 92.06 ± 5.57 (with coloured overlay) (Figure 7).

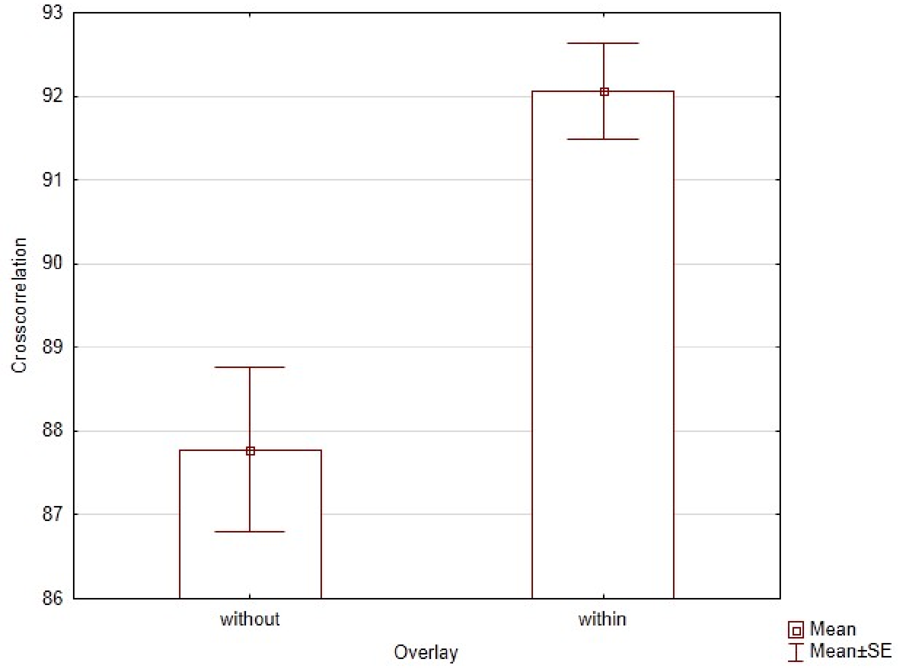

Figure 7: Cross-correlation (*y-axis*) without (CG, N = 118) and within (EG, N = 94) individually prescribed coloured overlay (*x-axis*)

- Comprehension Rate (CR):

CR during reading was 86.03 ± 10.53 when coloured overlay were not used and 88.69 ± 9.96 when they were used ($p>0.05$) (Figure 8).

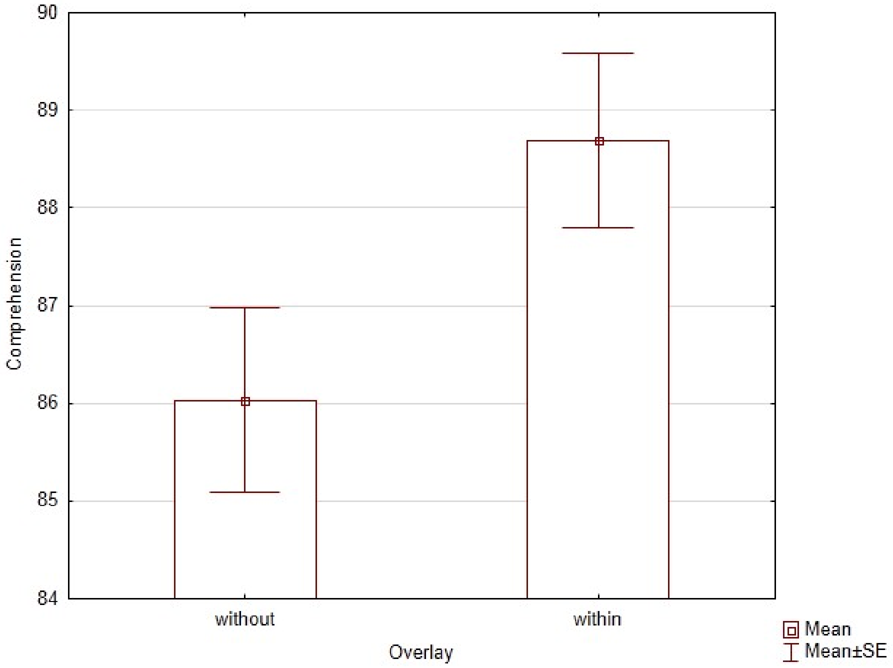

Figure 8: Percentage of Comprehension (*y-axis*) without (CG, N = 124) and within (EG, N = 124) individually coloured overlay (*x-axis*)

F. CONCLUSIONS (or expected outcomes)

The use of coloured overlay by an adult population suffering visual stress has been shown to significantly improve reading-related parameters, enhancing reading fluency. Even though the comprehension rate variable showed no statistically significant changes without (78.9%) and within (83.2%) the use of coloured overlay, this data can be useful to demonstrate that, instead of the increase in reading rate, no loss of comprehension has been seen.

Fast effortless word decoding associated with good comprehension is essential for a skilled reading. These skills are critical for a successful profession and social life nowadays.

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