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ERGONOMICS OF DIGITAL TABLETS IN OCCUPATIONAL USE: VISUAL AND KINEMATIC ACTIVITY OF HEAD MOVEMENTS UNDER THE INFLUENCE OF REFLEXIVE OFFENSES CAUSED BY LIGHTING

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Abstract: The paper presents a quantitative analysis of the influence of reflected glare from the tablet interface, generated in interaction with the environment lighting, on the visual activity and kinematics of head movements in search of a better visualization. The results did not show significant effects of glare on the variables studied, which is in contrast to the literature, strictly from non-quantitative research. Relevant aspects of this study are: the approach on little studied ergonomic issues; the application of integrated sophisticated equipment (eye tracker and head tracker) under a new research perspective; and the development of a quantitative method for the analysis of proposed questions.

Keywords: ergonomics of the tablet PC, posture and lighting, vision and lighting.

1. INTRODUCTION

In many situations, the introduction of new technology as an occupational tool requires an ergonomic review of the renewed work environment. For Moraes and Mont'Alvão (2010), the use of new instruments and/or materials in occupational environments commonly represents an ergonomic disorder, therefore it is essential to carry out an ergonomic work analysis (AET) when these changes occur. With the widespread implementation of occupational use of tablets in school and work environments, little attention has been paid to ergonomic principles for this process, at the same time that several ergonomic problems have emerged.

The approach of this study is justified due to the very common use of the tablet in a horizontal plane and the vehemence of the reflectance characteristic of its interface, which in interaction with the ambient lighting favors the occurrence of glare due to reflection, which can compromise the activity. and lead to the adoption of inappropriate body postures in search of a better visual condition. In the scientific bibliography and regulatory standards, several references are found about the negative effect of glare reflected on the performance of visual activity (LIRA, 1994; BRANDIMILLER, 1999; MORAES and MONT'ALVÃO, 2010; BRASIL, 2002; IIDA, 2005; VILLAROUCO and ANDRETO,

2008). Several references are also found about the effect of glare due to reflection on head postures for better visualization (BRANDIMILLER, 1999; DUL and WEERDMEESTER, 2004; LYRA, 1994; MORAES AND MONT'ALVÃO, 2010, RIO and PIRES, 2001 ; BRASIL, 2002; JUUL-

KRISTENSEN et al., 2004; IIDA, 2005; FERREIRA, SHIMANO and FONSECA, 2009).

When considering the recent development of the tablet by Apple in 2010 and its high acquisition cost,

as a technological innovation, it is possible to infer, even without specifying a date, that the spread of its use as an occupational tool is a relatively new trend. Abrahão (2000) states that the impact of new technology on the occupational environment has been approached from various angles and ergonomics is increasingly requested to analyze the process of introducing new technology, among others. In a bibliographical review, it was found that there is still no great demand for scientific research on the topic, especially related to the effects of glare reflected on visual issues and body posture.

In this context, this article presents an ergonomic review of the occupational use of tablets regarding the influence of glare due to reflection on the performance of the activity of visual exploration and kinematics of head movements in search of a better visual condition. It also presents a new perspective on the application of research equipment (integrated eye tracker and head tracker), and innovation with the development of a quantitative method for analyzing the ergonomic issues addressed.

2. OBJETIVO

The objective of this study was to quantitatively analyze the influence of glare reflected on the tablet interface on the performance of visual exploration activity and the kinematics of head movements in search of better visualization.

3. METHOD

3.1. Research subjects

The research was carried out with 10 participants of both genders, aged between 18 and 23 years old. The average age was 20.2 years, with a standard deviation of 21.8.

Inclusion criteria:

- Do not present severe postural changes or motor, neurological or musculoskeletal impairment evident on inspection, which in any way could interfere with the maintenance of sitting posture and head positioning.
- Do not wear glasses.
- No visual deficits, except when corrected with the use of contact lenses.
- Not have a diagnosis of dysfunction, disorder or disease that could compromise the reading and recognition of graphic characters, as well as their direction (right, left, up and down).

3.2. Ethical aspects

The research is approved by the Ethics and Human Research Committee of the Faculty of Philosophy and Sciences (FFC) UNESP de Marília, opinion number 702/2013. The Free and Informed Consent Form was applied, in accordance with Resolution 196/96 of the National Health Council, which deals with the Code of Ethics for Research on Human Beings.

3.3. Local

Data collection was carried out at the Information, Vision and Action Laboratory (LIVIA), of the Department of Physical Education of the Faculty of Sciences at UNESP,

- Bauru Campus.

3.4 Materials and equipment

- Eye-tracker model H6 from Applied Science Laboratories (ASL).
- Ascencion brand head-tracker Flock of Birds model.
- Apple brand tablet model iPad 2 64GB wi-fi, with 9.7' screen and an Apple brand support, to keep it at a 30° angle in relation to the table.
- Luxmeter, brand Lutron, model LX-101, calibrated.
- Portable digital luminance meter, brand Konika Minolta, model LS-110, calibrated.
- Table with horizontal surface.

Dimensions (width x depth x height) 1.30 cm x 59.5 cm x 75 cm, complying with NBR 13966 – Ergonomics, which establishes measurements between 72 and 75 centimeters for the height of the work table.

- A chair, without any type of adjustment, with a backrest at 90° in relation to the horizontal seat. Dimensions: (width x depth x height) 37 cm x 35.5 cm x 45 cm.
- Task prescribed with 140 graphic characters arranged in ten lines. The characters are optotypes, that is, standardized symbols for tests, which in this adaptation are represented by Landolt's "C", used for visual acuity testing.
- Tripod adapted to support the lighting system, mounted with a luminaire/rail with two lamps

Laboratory description

The table-chair set was positioned on fixed points marked on the floor and the center of the chair was kept aligned with the center of the table. The distance between the back of the chair and the front edge of the table was 41 cm centimeters. 80 centimeters behind the chair, the head tracker's electromagnetic signal transmitter was positioned, which, through the position and relative orientation of the sensor coupled to the eye tracker, tracks head movements (position and orientation).

The tablet was kept at a 30° tilt in the center of the table, at a distance of 65 cm between the participant's glabella in the standardized initial position and the point marked in the center of the upper edge of the tablet. The measurement is between the minimum and maximum limits of 45 and 70 centimeters respectively, recommended by FIOCRUZ (n.d.). To adjust this distance for each participant, a line was drawn in the center of the table, over which the tablet was moved back and forth and a 65-centimeter nylon line was used for measurement.

A luminaire and a tripod were adapted to compose the mobile lighting support system, which made it possible to generate and direct a range of

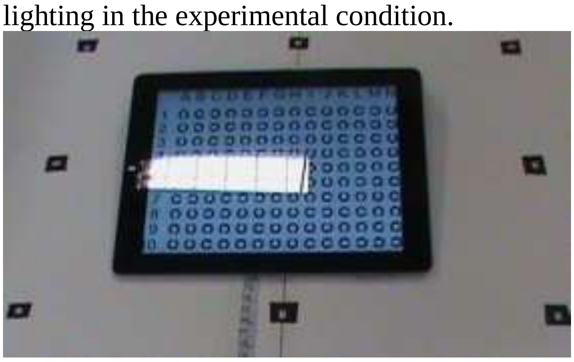
horizontal glare over a pre-determined area of the interface (lines 4, 5, 6 and 7), as shown in Figure 1. A marking drawn on the floor parallel to the participant and 40 centimeters from the right side of the chair was used as a reference for the movement back and forth, in order to direct the obfuscation over the lines of pre-determined characters in the interface.

Figure 1 – Experimental condition with the participant in the initial posture and their visual perspective of the interface at this moment.

Source: the author.

Figure 2 shows the tablet placed in the area used for data collection, still without the use of the lighting system of the experimental condition, therefore, with the interface exposed exclusively to the general and strictly artificial lighting of the laboratory, which is designed with luminaires similar to the one used in the research and comply with NBR ISO/CIE 8995-1 – Lighting of work environments, Part 1: Interior, of 04/21/2013. In the aforementioned figure it is possible to observe the great similarity between the reflection generated by the general illumination of the laboratory, which represents a natural condition of use of the instrument and the reflection generated by the lighting of the experimental condition.

Figure 2 - Reflection generated by artificial lighting in the laboratory without using the lighting in the experimental condition.



Source: the author

The luminance of the experimental condition created in the laboratory was measured at 920 lux. The lux meter's photocell was positioned on the tablet interface to record luminance, according to the instructions in NBR ISO/CIE 8995-1.

The intensity of light reflected on the tablet interface was measured with a portable digital luminance meter and determined in candelas per square meter (cd/m²). The numbers recorded were:

- Between 397.5 and 460 cd/m² in non-reflective interface areas.
- 9205 cd/m² in the reflective area.

3.6 Experimental protocol

The task consisted of visual observation to identify and verbalize the direction (right, left, up and down) in which the “C” optotype has an opening. These graphic characters were read once and in the same direction as the reading in Brazilian Portuguese. The time to perform the task was not predetermined.

During the placement and adjustment of the eye tracker, the general lighting in the laboratory (strictly artificial) remained on and the lighting designed for the research turned off, in order to facilitate the calibration of the instrument, necessary for each participant. The tablet was positioned on the table only after calibration to enable the points marked on the table, necessary for this process, to be viewed by the participant.

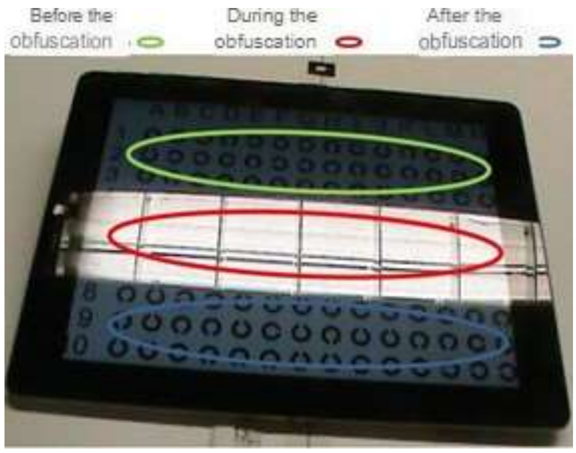
With the position of the table-chair set determined by points marked on the floor and with the tablet placed on the table with an inclination of 30°, the participants were positioned in a sitting posture and with the hip angle at approximately 90° using the back of the chair. In this position, the distance between the marking in the center of the upper edge of the tablet and the participants' glabella was measured at 65 cm. For the measurement, a 65 cm long nylon rope was used and the tablet was moved back and forth. aligned with the marking made on the table. With the participants still in this position, the lighting system designed for the experimental condition was turned on and the general lighting in the laboratory was turned off. Using the mobile lighting system, the lamp was moved to direct the glare to the pre-determined area of the task interface from the visual perspective of the participant, who reported the location of the glare using the respective line numbers.

After these procedures, the eye tracker with integrated head tracker and the video camera used to record the experiment were turned on and then the participant began the task following the instructions under the researcher's voice command. During the experiment, participants were free to move and adopt convenient, habitual or necessary body postures to perform the task.

3.7 Procedures for data analysis

The data were exported from the collection system and processed in a Matlab routine, structured to distinguish the areas of the interface corresponding to, before the glare, during the glare and after obfuscation, which were named as shown in Figure 3.

Figure 3 - Distinction of interface areas in Matlab programming for data analysis.



Source: the author

In the initial posture, it was intended that all participants viewed the glare over a pre-determined common area, corresponding to lines 4, 5, 6 and 7, which was not possible for all participants, as shown in Table 1. For In these cases, a variable was developed in the Matlab routine with the description of the location of the glare, from the visual perspective of these participants, similar to the way shown in the following table.

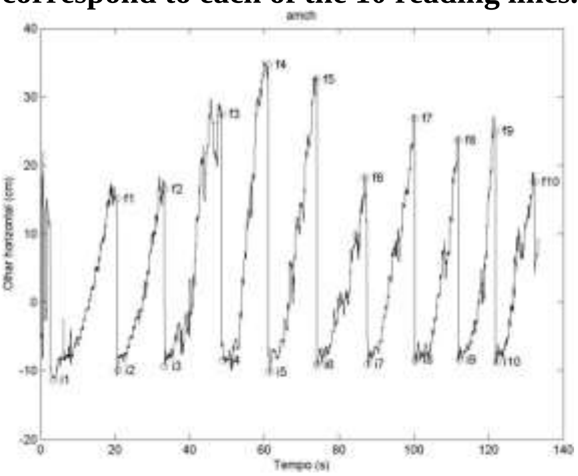
Table 1- Visual perspective of participants who observed glare utside pre-determined areas.

Participant	Visualized the glare between the lines
P 16	4 a 8
P 17	4 a 8
P 20	4 a 8
P 24	3 a 8

Source: t

To obtain exclusive data on the reading periods of the optotypes, another routine was created in Matlab to generate graphs of the horizontal gaze line arranged in time, in which, through visual observation, the starting and ending reading points of each line of optotypes were identified and marked manually with mouse clicks, as shown in Figure 4. In this way, part of the data, corresponding to before the beginning and after the end of the experimental period, as well as saccadic movements were excluded.

Figure 4 - Example of a horizontal gaze graph with markings (red circles) at the beginning (i) and end (f) of the reading of the optotypes in each of the ten lines. The numbers that accompany the letters correspond to each of the 10 reading lines.



Source: the author

With these procedures, the data for statistical analysis was configured. With a parameter on the horizontal line of gaze, data relating to the reading time (dependent variable) elapsed on the lines included in the different areas of the interface, before, during and after glare (independent variables) were used to analyze visual activity.

Considering that the data on eye and gourd movements were collected through integrated systems (eye tracker/head tracker), therefore synchronized and on the same temporal scale, the analysis of the kinematic data of the head movements corresponding to the same time periods established for the analysis of visual activity. Therefore, data on variability (standard deviation) of head position, coordinates of the X, Y and Z axes and head orientation were analyzed, azimuth, elevation and roll rotation angles (dependent variables), performed in different areas of the interface, before, during and after the glare (independent variable).

3.8 Statistical analysis

Data for each dependent variable were subjected to analysis of variance (one-way ANOVA) of repeated measures for the effect of glare with three levels (before, during and after glare). Pairwise comparisons of means were performed using the Tukey LSD test, when necessary, applying the Bonferroni probability adjustment. In analyzes in which the data did not meet the assumption of sphericity, Greenhouse-Geisser adjustments were used. The significance level adopted was 0.05 for all analyses.

4. RESULTS

4.1 4.1 Horizontal look

The average reading time of the optotypes was not affected by glare, F (1.5, 13.4) = 0.97, p = 0.38. The values Means (standard errors) of reading time were 12.1 (0.57), 12.3 (1.03) and 11.3 (0.45), respectively for situations before, during and after glare.

4.2 Kinematics of head movements

The average values referring to head movements, performed during the reading periods in each area of the interface, were also not significant for the glare effect.

Head position:

➢ X-axis: F (1.29, 11.58) = 1.55, p =

0.25. The mean values (standard errors) were 1.03 (0.31), 0.75 (0.20) and 0.44 (0.07), respectively for the situations before, during and after the glare.

➢ Y-axis: F (1.2, 10.8) = 0.94, p =

0.37. The mean values (standard errors) were 0.40 (0.09), 0.45 (0.14) and 0.54 (0.21), respectively for the situations before, during and after glare.

➢ Z-axis: F (1.27, 11.40) = 0.64, p = 0.48. The mean values (standard errors) were 0.16 (0.06), 0.13 (0.02) and 0.11 (0.02), respectively for the situations before, during and after the glare.

- Head orientation: Azimuth rotation angle: F (1.5, 13.8) = 0.13, p = 0.83. The mean values (standard errors) were 0.8 (1.1), 0.8 (0.13) and 0.7 (0.1), respectively for the situations before, during and after the glare.
- ➢ Angle of rotation elevation: F (1.3, 11.3) = 4.07, p = 0.06. The mean values (standard errors) were 0.82 (0.13), 1.15 (0.16) and 1.37 (0.31), respectively for the situations before, during and after glare.
- ➢ Roll rotation angle: F (1.18, 10.6) = 1.01, p = 0.35. The mean values (standard errors) were 0.50 (0.15), 0.64 (0.22) and 0.64 (0.27), respectively for the situations before, during and after glare.

5. DISCUSSION

Regarding the kinematics of head movements, the results obtained indicate that there were no significant postural adaptations for better visualization, which contradicts the bibliographical references, (BRANDIMILLER, 1999; DUL and WEERDMEESTER, 2004; LYRA, 1994; MORAES and MONT' ALVÃO, 2010; RIO EPIRES, 2001; BRASIL, 2002; JUUL-

KRISTENSEN et al., 2004; IIDA, 2005; FERREIRA, SHIMANO and FONSECA,

2009). These references do not mention the reflected glare generated by the tablet interface, however they are commonly considered in the academic and scientific areas and by regulatory standards, as applicable to any occupational condition in which reflective glare occurs.

As for the performance of visual activity, the result demonstrates that it was not affected by reflected glare. For Villarouco and Andreto (2008), the quality of lighting is an element that modifies performance. In this sense, Lyra (1994) states that glare in the work environment reduces visual capacity. This result is also contrary to the bibliographic consensus regarding the deficient effect of glare on the performance of visual activity (BRANDIMILLER, 1999; MORAES and MONT'ALVÃO, 2010; BRASIL, 2002; IIDA, 2005).

The adoption of strategies to avoid reflected glare, capable of avoiding deficits in the performance of visual exploration activities, were already expected, but it was also expected that these strategies would be represented by postural compensations, determined mainly by head movements.

A likely hypothesis to be suddenly raised by the reader is that the trunk flexion and extension movements were used by the participants to get rid of the reflected glare, a fact that would justify the results found on the kinematics of head movements and to a certain extent would disqualify the methodology used. However, these movements would have been detected indirectly by the head tracker; more precisely, they would be identified in the "X axis" variable, considering that the head moves along the trunk during flexion and extension movements. The hypothesis is believed to be plausible that, in this simulated condition of a workstation, the reflected glare does not exert a significant influence on visual exploration activity and head movements due to the proportion of the interface dimension in relation to the field of vision, a condition that , which is also related to the distance between the participant's eyes and the interface. In other words, the larger the real physical dimension of the interface and the greater the proportion of this dimension in relation to the distance to the eyes, the less significant the head movements will be to aid the visual search for information without deficient temporal performance.

There are several postural strategies that can be adopted in search of better visualization due to reflected glare, however, it is physiologically less costly to move the eyes than the head.

One hypothesis to be raised is that individuals with an age range like that of the participants in this study may be accustomed/adapted to glare conditions, due to the frequent use of devices with high reflectance interfaces such as touch screen cell phones, tablets, notebooks with screen touch among others, which could lead to the development of skills to overcome glare such as through less sensitivity to light. Factors such as the pleasure of use or the symbolic value given or added to a certain technological device can mean that reflected glare is not perceived as an important visual deficit and in this way strategies and skills are acquired to overcome the deficient visual condition, which each It increasingly requires less physiological demand (in this case, head movements) for the device to become functional; that is, human adaptation occurs to maintain the usability of technological devices. This hypothesis can be reinforced when considering that many devices with a highly

Reflective lights are commonly used in environments with natural lighting, where the magnitude of glare tends to be much greater than that presented in the experimental condition.

From the design perspective of industrial design and according to Lobach (2001), for the configuration of products, aesthetic, functional and symbolic functions are considered. The excessive brightness of the tablet screen, which makes the surface very susceptible to glare due to reflection, may be related to the predominance of the product's aesthetic configuration over functionality. According to Iida (2005), from the consumer's point of view, technical, aesthetic and ergonomic quality are desirable characteristics in a product. Culturally, aesthetic qualities are highly valued, to the point that the excessive brightness of the tablet screen, which adds aesthetic value, is commonly not perceived and addressed as a direct problem for the visual issue and an indirect one for the postural issue. Perhaps factors linked to the design and consumption of products can lead users to develop auxiliary strategies to overcome the visual problems demanded by reflected glare, as well as their technological needs and anxieties.

6. CONCLUSION

The scientific theoretical structure presented in this work, regarding the study of the occupational use of the tablet, was developed permeating regulatory standards, ergonomic recommendations and specialized bibliographic references, in order to contextualize and support the ergonomic issues of the research, as well as to support the construction of a Research Methodology. Numerous considerations are found about the influence of reflected glare on the performance of visual activity and the adoption of inadequate postural compensations in search of a better visual condition. However, these considerations are carried out without the application of instruments and metrics capable of generating quantitative data. The results obtained in this research, with the application of instruments that support the quantitative analysis of the same aspects, are contrary to the bibliographical references. These results are part of a larger ongoing project in which other methods, factors and other lighting conditions with vertical glare at the interface are analyzed. In this way, more comprehensive considerations can be established in the future.

The approach to issues that stand out in the research

important and little studied ergonomics; the application of sophisticated equipment from a new research perspective; and the development of a quantitative method for analyzing the visual and kinematic activity of head movements in individuals subject to reflection glare.

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