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ERGONOMIC ANALYSIS USING EYE TRACKING: THE POSITIONING OF A BAJA CAR'S DISPLAY

Eugenio Andrés Díaz Merino[1]*

Diogo Pontes Costa[2]

Carmen Elena Martínez Riascos[3]

Erika Danielly Florêncio Pereira Muniz[4]

Irandir Izaquiel Paulo[5]

Giselle Schmidt Alves Díaz Merino[6]

Abstract

The BAJA SAE Brazil competition is organized by the Society of Automotive Engineers (SAE). It challenges engineering students to develop prototype off-road vehicles. This article aimed to use Eye Tracking in the analysis and definition of the display positioning in the Puma car used for the BAJA competition by the team from the Federal University of Santa Catarina, with a focus on driver ergonomics and positioning. The study utilized Eye Tracker from Senso Motoric Instruments (SMI) in combination with BeGaze software. Two team drivers participated in the tests, representing the 5th (P5) and 50th (P50) percentiles. Three different display positions on the vehicle's dashboard were evaluated. The results revealed that display position 02 offered the best performance, providing greater efficiency in viewing the indicator lights and speedometer on both straight and curved trajectories. However, a limitation was observed in reading information located to the left of the speedometer, attributed to the shape of the steering wheel. Based on these findings, design improvements were proposed, including adjustments to the display's angle and height, repositioning the speedometer, redesigning the steering wheel, and adapting the seat. These proposals aim to comply with competition regulations while addressing the drivers' needs. This study highlights the importance of Eye Tracking as a tool for enhancing the ergonomic design of Baja vehicles, contributing to safety and more functional solutions.

Keywords: Eye Tracking. Ergonomics. Baja SAE racing car.

1. Introduction

In order to promote knowledge and technological updating of the mobility industry, focused on innovations and industry trends, the *Society of Automotive Engineers (SAE)* was established in New York in 1905. The association encourages the theoretical and practical

[1] Federal University of Santa Catarina (UFSC) / PPGEP – Graduate Program in Production Engineering - Department of Production Engineering. https://orcid.org/0000-0002-7113-6031. *eugenio.merino@ufsc.br.
[2] Federal University of Rio de Janeiro (UFRJ).https://orcid.org/0000-0001-8330-7208.
[3] State University of Santa Catarina (UDESC) / CEART, http://orcid.org/0000-0001-6823-8144.
[4] University of the State of Amapá (UEAP). https://orcid.org/0000-0003-2422-2604.
[5] Federal University of Santa Catarina (UFSC). https://orcid.org/0000-0003-3483-9632.
[6] State University of Santa Catarina (UDESC) / CEART, Federal University of Santa Catarina (UFSC) / Post-Design. https://orcid.org/0000-0003-4085-3561.

improvement of engineering students and the like, applying in practice the knowledge acquired in the classroom, aiming to increase their preparation for the job market. The association annually promotes dozens of events, including symposiums, forums, colloquia, lectures and congresses, which are attended by more than 15 thousand participants, among the events is the *off-road vehicle competition*, with "Baja" being the term that refers to this specific type of competition, usually held in challenging and rugged terrain. These competitions are held on difficult trails, which can include sand, mud, rocks, and other natural obstacles. The Baja competitions promoted by SAE have their origins in Baja California, Mexico.

In Brazil, SAE was established in 1991, holding regional competitions from Baja SAE to move on to national competitions where the winning teams are invited to participate in the international competition, in the United States. By participating in the Baja SAE program, the student gets involved with a real case of developing an *off-road* vehicle, from its conception, detailed design, construction and testing. The purpose is to create reliable, easy-to-maintain, economical and **ergonomic vehicles**, meeting the requirements of the BAJA SAE Brasil regulation (SAE, 2021). Since 1997, the Federal University of Santa Catarina (UFSC) has participated in the competition, currently with the UFSC Baja SAE team, composed of students from different areas, especially engineering and physics, who work in all phases of development including design, construction, testing, promotion and operation (BAJA UFSC, 2024).

In this scenario, Ergonomics is crucial to provide **safety and comfort to pilots**, becoming a competitive advantage for the team when evaluating the interaction between humans and products in specific contexts (Iida and Buarque, 2016). Ergonomics is a science that studies the interactions between people and elements of a system, applying theories and methods to optimize human performance and well-being (ABERGO, 2022). Ergonomic evaluations can be carried out in real environments or in simulated contexts (such as the one carried out in this project) that allow the establishment of recommendations to improve the characteristics of products or activities.

However, analyses in simulated contexts are challenging due to the complexity of the interactions and variables involved. Fialho, Braviano and Dos Santos (2005) state that the ergonomist's task is to minimize the difference between the simulated and the real in order to obtain more accurate and satisfactory results.

According to Mondelo *et al.* (2004), most workstations are strongly related to the user's field of vision, requiring analysis of the position of the head and eyes in relation to the hands or specific parts of the workstation. Vision is a cyclical process that begins with a low-resolution peripheral stimulus, drawing attention to more detailed analysis. Next, the focus is directed to the first area of interest, and finally, the fovea inspects the object at high resolution (Duchowski, 2017).

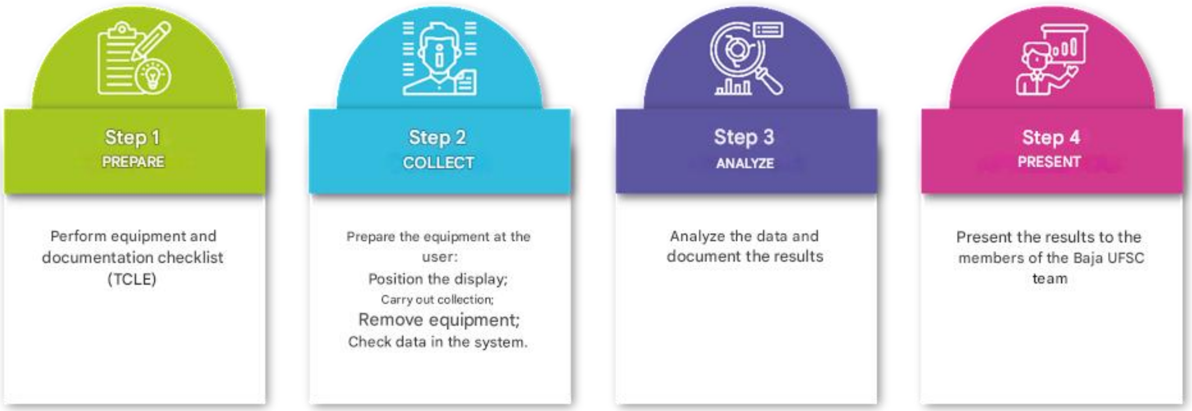
Thus, the use of technological resources such as *Eye Tracking* can increase the effectiveness of qualitative and quantitative analyses. This technology helps to understand visual tension by detecting where and for how long users fix their gaze and the path taken by their eyes. Applied in ergonomics, cognitive psychology, marketing and human-computer interaction (Schall; Bergstrom, 2014), this psychophysiological technology generates quantitative data on emotional variations and satisfaction. It records eye movements, such as blinks and fixations, and the analysis software maps this data from the image observed by the user (Gobbi *et al*., 2017).

In view of this, the objective of this research was to integrate *Eye Tracking* in the analysis and definition of the positioning of the *display* of the puma car used for the Baja competition by the team from the Federal University of Santa Catarina, considering the ergonomics and positioning of the driver.

2. Materials and methods

The present research is of an applied nature, with a qualitative-quantitative, exploratory and descriptive approach. The research was divided into two phases. The first is theoretical with the foundation of the main themes and the second with the execution, data collection, analysis and selection of the position. This second phase was developed in four stages, namely: (1) Prepare, (2) Collect, (3) Analyze and (4) Present, as described in Figure 1.

Figure 1 – Stages of the second phase



Source: authors (2024)

In preparation (Stage 1), the operation of the equipment was verified and the material used in the collection was prepared, namely: Free and Informed Consent Form (ICF), *Eye Tracker equipment (Senso Motoric Instruments SMI), iView ETG and BeGaze software,* smartphone, camera and camcorder, chargers and batteries of all equipment. In Stage 2, the following information was collected: full name, age, gender, height, and weight. The distances applied between the pilot and the panel were surveyed; pilot and ground; and panel – floor. In the vehicle, three display positions were considered, each position was previously tested and indicated by the BAJA UFSC team, based on the competition regulations and previous experience of the pilots.

Regarding the task prescription, it was defined that for each display position, the user should rotate the steering wheel from the point of origin to the 90-degree angle, simulating the curve movement, for 50 seconds with an interval of 10 seconds (Figure 2).

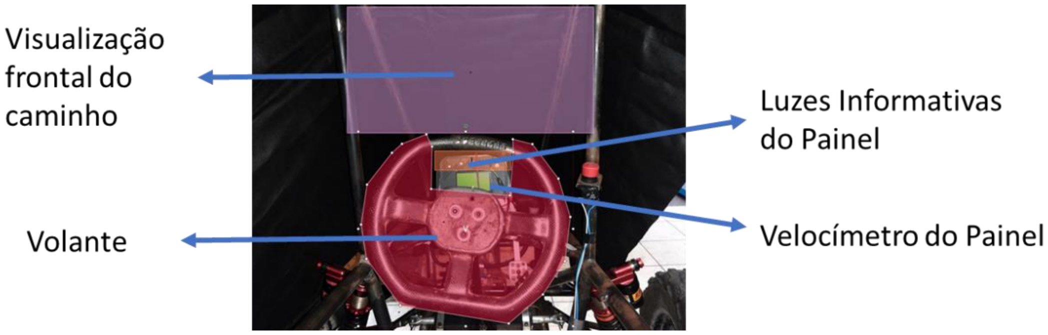
Figure 2 – Simulation of the curve movement

Source: NGD-LDU/UFSC Collection (2024)

The data generated by the Eye Tracking equipment (*Senso Motoric Instruments* - SMI *glasses)* were recorded with the aid of the *iView ETG* software. The characteristics of the test environment were also recorded, through video and photos.

The analysis (Step 3) was done using *BeGaze Eye Tracking* software, for this activity photographic records of the reference area and the selection of areas of interest (AOIs) were included: Informative Panel lights; Dashboard Speedometer; steering wheel; frontal view of the path, as shown in Figure 3.

Figure 3 – Areas of Interest



Source: authors (2024)

With the data provided by *Eye Tracking*, the data were analyzed in a qualitative-quantitative way, aiming to identify and recommend the best positioning of the *display*, which contains the digital speedometer and informative light emitters. The following were considered: **position of origin of the flywheel, position of curve of the flywheel, performance indicated in the AOI analysis** and **number of fixings**. To deliver the result of the analysis (Stage 4), an online meeting was held with all users of the survey, through a virtual platform, presenting the results, along with the justifications and conclusions.

Regarding the site of the experiment, it was carried out at the Florianópolis Campus (Department of Mechanical Engineering), of the Federal University of Santa Catarina, with 2 students and drivers of the car, one of the 5th percentile (P5) and the other 50th (P50). The users were volunteers and signed a Consent and Informed Form (ICF), according to Resolution items IV.3 of Resolution 466/12 of the CNS.

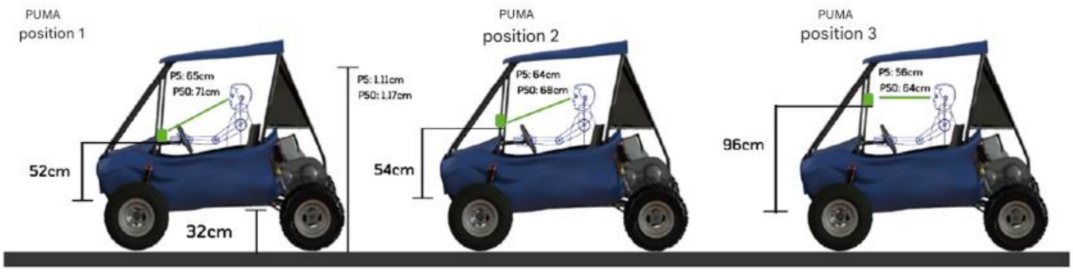
The object of this research was the BAJA car of the UFSC team, specifically the PUMA car (Figure 4).

Figure 4 – Puma Car

Source: https://baja.ufsc.br/nossa-historia/

The position selected to test the location of the *display* was defined by the project team and is presented in figure 5. During the collection, the *display* was located in the three positions and the test was carried out with each pilot.

Figure 5 - Display Position



Source: authors (2024)

3. Findings

In Stage 1, the equipment and materials were checked, namely: *Eye Tracking* equipment; *iVewETG* and *BeGaze software*; *smartphone*; camera; ICF; script and image to aid calibration. Stage 2 began with the preparation of the environment and positioning of the users in the car, then the glasses were assembled according to the protocol for using the equipment. Finally, there was the calibration of the glasses and the start of the collection. This procedure was performed on each participant. The first user (P5) was 19 years old, 49 kg, 1.60 cm tall, with an arm reach of 73 cm. The second user (P50) was 22 years old, 70 kg, 1.75 cm tall, with an arm reach of 76 cm. Both do not wear prescription glasses.

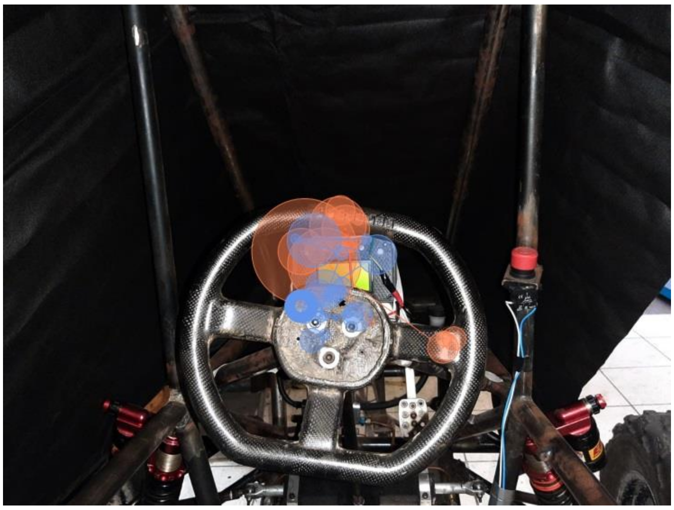
For **Stage 3,** the three positions of the display were tested and collected with each user.

First display position

User **01 (P5)** in the **position of the steering wheel origin**, was able to see all the informative lights on the dashboard with a wide view of the speedometer area and the path. User **02 (P50),** in the **original position of the steering wheel,** could not see all the information lights on the dashboard, but was able to see the speedometer in the path viewing area, without difficulties.

In **the steering wheel cornering position, user 01(P5)** can partially see the dashboard information lights, but loses sight of the speedometer area. Due to the shape of the steering wheel, there is a decrease in the front viewing area, but it is still possible to view without difficulty. User **02 (P50)** had the total loss of the view of the dashboard lights and a part of the speedometer, in addition, he also lost part of the view of the path. Figure 6 shows the tracking of both users, with the orange color corresponding to user 01 and blue to user 02.

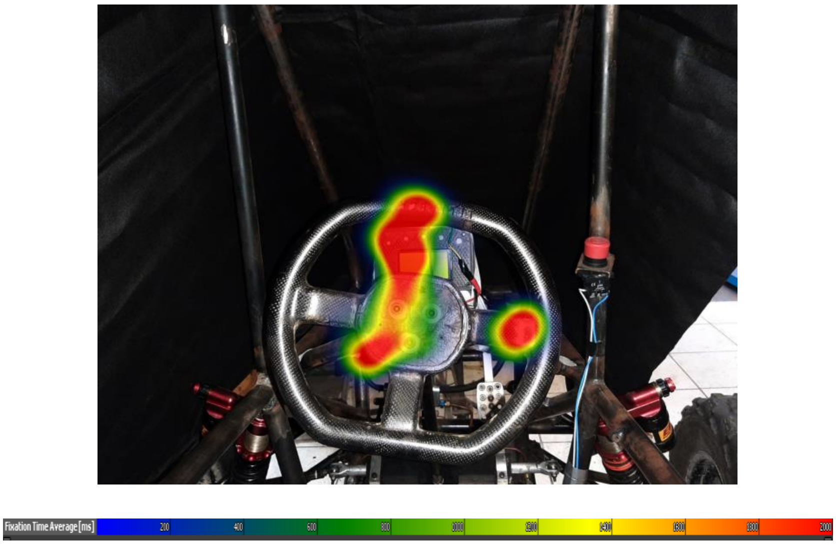
Figure 6 – Users' gaze path in the first position of the display



Source: NGD-LDU/UFSC Collection (2024)

When analyzing the information from the **heat map**, Figure 7, which represents the user's viewing time in each fixation, it was possible to show how users spent most of the time fixing their gaze on the steering wheel, and in this position of the *display* the steering wheel was interfering in a part of it, making it difficult to see some information.

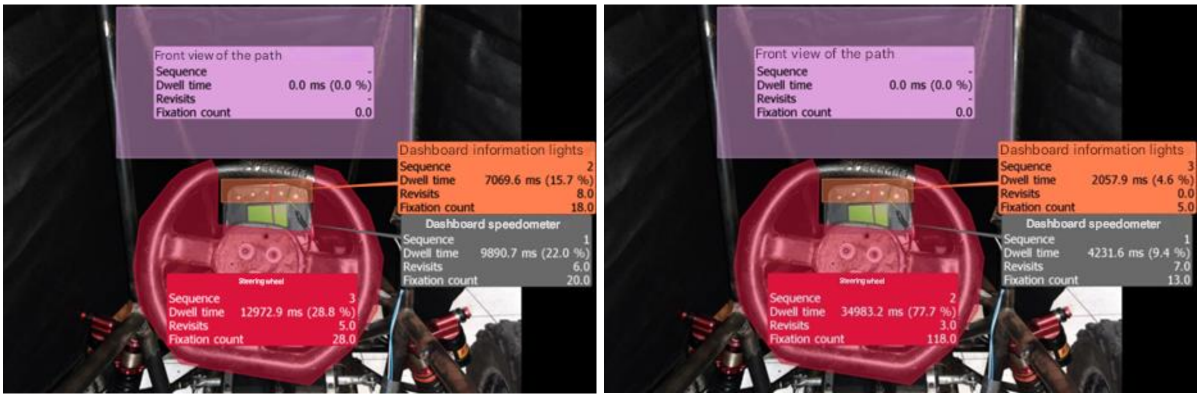
Figure 7 - Heat map both users



Source: NGD-LDU/UFSC Collection (2024)

By analyzing the **performance indicators**, used to evaluate the Areas of Interest (AOIs), it was possible to identify the visualization characteristics of the users in the informative lights of the panel; Speedometer; Steering wheel and in the front view of the path. User **01(P5)** looked first at the speedometer area, then at the information lights, and finally at the steering wheel. The area with the greatest attention from the user was the speedometer with 28 fixings and five revisits, followed by the lights area with 18 and 8 revisits. **User 02 (P50)** looked first at the speedometer area, followed by the steering wheel area, and finally at the information lights. The area that most focused attention was the steering wheel with 118 times and three revisits, followed by the speedometer area with 13 fixations and seven revisits (Figure 8).

Figure 8 - Performance indicators in AOIs users 01 and 02

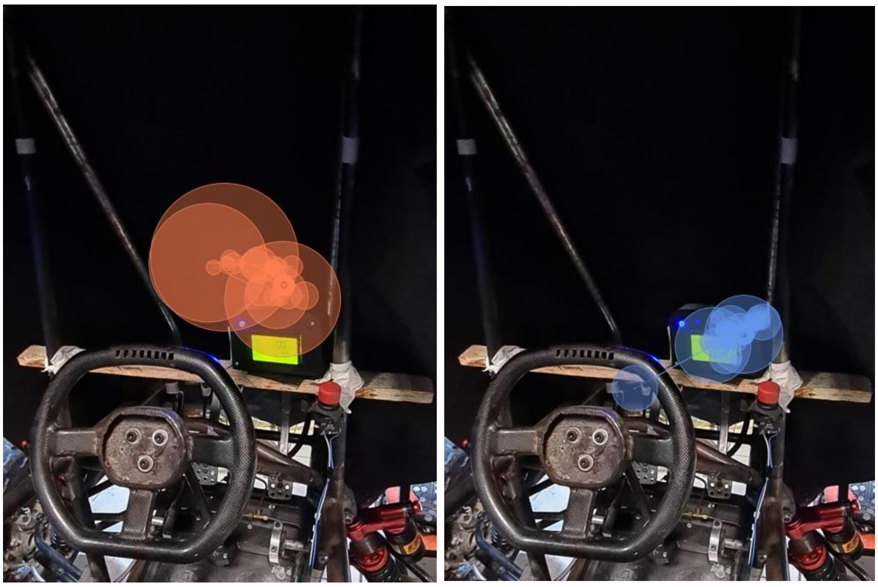


Source: NGD-LDU/UFSC Collection (2024)

Second Display Position

User 01(P5) in the **original position of the steering wheel** was able to see the path area, the speedometer and the steering wheel, but did not see all the lights on the dashboard. User **02 (P50)** was unable to see all the information lights or the speedometer. Regarding the **steering wheel curve position,** both users partially viewed the speedometer and lights, but there was a loss of vision of a part of the frontal area, specifically where the dashboard is located (Figure 9).

Figure 9 – Path of gaze in the second position of the *display*



Source: NGD-LDU/UFSC Collection (2024)

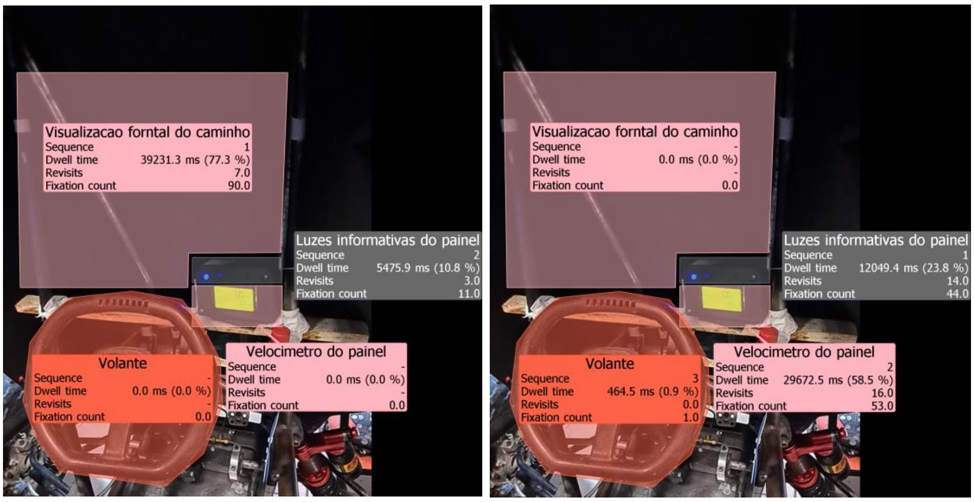
Analyses using the **heat map**, Figure 10, identified elements of the *display* that generated continued interest and engagement from riders. This analysis uses a range of colors that goes from blue, through green and yellow to red, the longer the rider looks at a point, the more intense the hue. In position 2 of the *display,* the drivers looked for a longer time at the upper side of the display, where the information lights and speedometer are located.

Figure 10 – Heatmap Both Users

Source: NGD-LDU/UFSC Collection (2024)

Regarding the **performance indicated in the AOI** analysis, Figure 11, **user 01(P5)** first looked at the path visualization area, where she stayed most of the time (70.3%), then directed her gaze to the region of the indicator lights of the panel, where she stayed 11% of the time. User **02 (P50)** looked at the speedometer 58.5% of the time, in the region of the information lights 23.8% of the time. Unlike **user 01(P5),** there was a fixation of the gaze on the speedometer, on the informative lights and on the steering wheel, but did not see the area of visualization of the path.

Figure 11 - Performance indicators in AOIs users 01 and 02



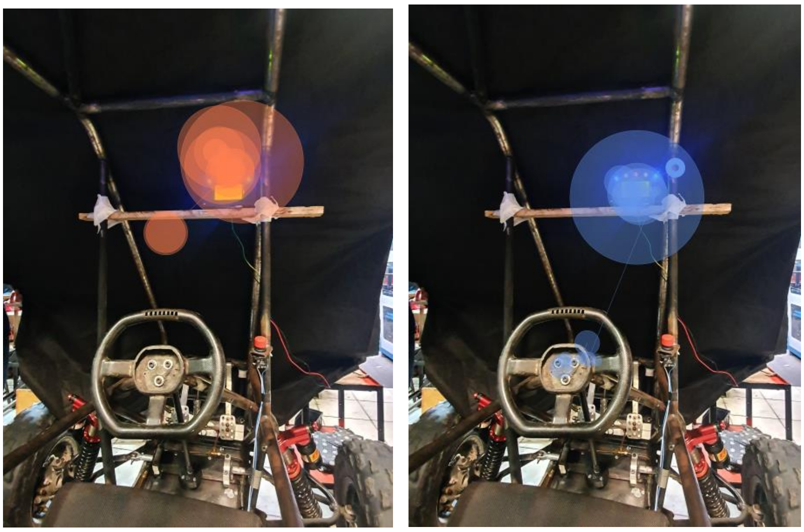
Source: NGD-LDU/UFSC Collection (2024)

Third *display position*

User **01(P5)** in the **original position of the steering wheel** when she is in the position of the face to view the lane, can only see the speedometer, to look at the informational lights it is necessary to tilt the face, however, when this happens, she loses visual contact with the steering wheel and the focus of the lane. **User 02 (P50)** in **the original position of the steering wheel** has a good adequate view of the dashboard and the windshield region, however, when there is a need to look at the steering wheel area, there is a loss of visual contact with the dashboard information. Unlike user 01 with the height corresponding to P5, it was not necessary to rotate the head.

In the case of **the steering wheel curve position**, both users obtained results similar to the analysis of position 01 of the *display*, because when user 01 turns the steering wheel to make the turn, there are considerable losses in visualization, either of the dashboard or of the steering wheel. Figure 12 shows the curve position of the steering wheel, the graph in orange corresponds to user 01, and to user 02, in blue.

Figure 12 – Path of gaze in the third position



Source: NGD-LDU/UFSC Collection (2024)

In the third position of the *display*, the analysis of the **heat map** allowed us to confirm the place where the pilots stayed most of the time, Figure 13. It should be noted that at this point the drivers slightly averted their eyes from the path of the track to be able to see the details on the display. Users were able to find what they are looking for, but they had to tilt their heads more, which can cause discomfort when the competition route is long.

Figure 13 - Heat map in the third position of the display

Source: NGD-LDU/UFSC Collection (2024)

Regarding the **performance indicated in the AOI analysis,** of **user 01(P5),** it is perceived that it sought, in the first place, to visualize the informative lights. Then, he viewed the speedometer and then the area where he saw the path. In this area, the user looked for 13.8% and revisited three times. **User 02 (P50), on the other hand**, first viewed the informative lights on the dashboard, but remaining only 4.9% and with six revisits. Then, he visualized the steering wheel, where 4.6% remained and revisited once. The speedometer area was visited, after the one on the way, but it was where the user stayed most of the time (50.3%) and revisited it three times.

Regarding the **number of fixations** of **user 01(P5)** gaze in the marked areas, it is possible to observe that the largest number of fixations was in the areas of the lights (53.9%) and the area of visualization of the path in 13.8% of the time. On the other hand**, for user 02 (P50),** it was possible to observe that the largest number of fixations was in the speedometer area (50.3%, Figure 14).

Figure 14 - Performance indicators in AOIs users 01 and 02

Source: NGD-LDU/UFSC Collection (2024)

4. Conclusions

This article used *Eye Tracking* to analyze and identify the best positioning of the *display* of the Puma car of the Federal University of Santa Catarina team for the BAJA SAE competition, generating recommendations to optimize users' access to dashboard information during the race.

The characteristics of the display visualization were analyzed, at three different heights, to confirm how the drivers saw the information on the dashboard in the original position of the steering wheel, the steering wheel curve position, how the performance indicators behaved in the AOI visualization and the number of fixations. With this, it was possible to recommend that the team use positioning 02 of the *display*, with small adjustments to better meet the competition guidelines and the comfort of the drivers.

The help of technological instrumentation was crucial in the recommendation, due to the analysis based on the data and observations of the pilot and context, thus avoiding subjectivity in the team's decision-making regarding the arrangement of the panel elements. The results highlighted how adjustments in the angle, height and arrangement of the elements on the panel can improve the interaction of the pilots with the vehicle, contributing to a more competitive performance in BAJA SAE Brazil.

It is therefore recommended to use *Eye Tracking* in all stages of prototype development, covering both preliminary analysis and final tests. This approach helps in understanding the visual behavior of pilots, identifying where and for how long their gaze is fixed. Based on this data, it is possible to make precise adjustments to the arrangement of the dashboard elements, ensuring greater efficiency in the interaction and accessibility of information during the use of the vehicle.

Future studies with the use of this technology can allow professionals to identify trends and patterns of user behavior in various activities such as interaction with products, equipment, improve the usability of websites or interfaces, as well as fix training information and the relationship with the worker's cognitive processes.

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