Interaction Analysis and Usability Adjustments in Conceptual Design of a Generic Tractor Cabin

Natalia Villalpando-Chávez(✉), Cristina Vázquez-Hernández, María Fernanda Aldana-Castillo, and Pilar Hernández-Grageda

Universidad Panamericana Campus Guadalajara, Calzada Circunvalación Poniente N. 49, Zapopan, México
{0215080,0213780,0215201,phernand}@up.edu.mx

Abstract. Considered to be the most used machinery in agriculture and forestry, and being the interior of a tractor's cabin the place where the user gets involved and develops most of the tasks every day at this industry, the design and construction of standard tractors cabins should contemplate ergonomic strategies and design principles in order to guaranty an improvement of the user's work efficiency, comfort, health, and safety based on tractor requirements standardized by SAE (Society of Automotive Engineers), ISO and safety range tests. The purpose of this job is to present a new proposal for the interior of a tractor's cabin based on a conceptual design, as a result of combining the findings of a literature review with design and decision-making methodologies, providing visual, biomechanics, posture, and tool simplification refinements in the frontal panel, multipurpose accessories' area, lever system, and the seat.

Keywords: Tractor cabin · User experience · Usability · Product ergonomics · Transportation design

1 Introduction

Tractors constitute one of the most used machinery in agriculture but are not designed for the user's comfort and safety, provoking musculoskeletal injuries and long-term health damage [1]. If a design is grounded in Ergonomics, the outcomes can optimize human well-being and overall system performance [2]. Ergonomics ease the analysis of user experience, being the driver in this case. The objective of this article is to implement a user-centered approach that considers usability testing, cognitive processes, and tasks hierarchization, for proposing specific ergonomic adjustments in order to combine physiological, anthropometric, and biomechanical improvements within a chosen tractor's cabin.

SAE (Society of Automotive Engineers) and ISO (International Organization for Standardization) identify standardized parameters when working with tractors, and safety ranges tests need to be implemented to maintain the driver inside the 30% of risk at the moment of tractor operation [3]. This way, the level of musculoskeletal injury exposure will reduce.

N. L. Black et al. (Eds.): IEA 2021, LNNS 221, pp. 284–290, 2021.
https://doi.org/10.1007/978-3-030-74608-7_36

Design and sizing of products should ensure accommodation, compatibility, operability, and maintainability by the user population. Generally, design limits are based on a range of the user population from the 5th percentile values for critical body dimensions, as appropriate. The use of this range will theoretically provide coverage for 90% of the user population for that dimension [4].

This work presents a redesign applied mainly to four zones of the tractor's cabin: frontal panel, multipurpose accessories area, lever system, and the seat; in a way that it decreases the number of components in the cabin, but increases its control, accessibility, and user performance. It applies ergonomic strategies focused on improving the user experience of the tractor's operator and proposes a conceptual design that combines physiological, anthropometric, and biomechanical adjustments inside the tractor's cabin, beneficiating the interaction between the operator and the elements of the cabin.

2 Method

2.1 Literature Review

Literature review and commercial research were made for detecting those elements involved in the interior of a tractor cabin and the possible matters in the interaction between operators and those elements. They were broken down into smaller sections for better understanding of the operations made by these parts. In addition, a reverse brainstorming method [5] was used to establish and prioritize ergonomic intervention strategies inside the cabin, based on the weaknesses spotted in each section previously detected. Finally, usability goals were used to assure how the new design would grant the highest achievable level of effectiveness, efficiency, and safety.

2.2 Procedures Analysis

Based on the findings from the literature review, a Procedures Analysis was performed to focus on the cognitive processes made by the users and to find the critical points in which we could intervene to minimize the mental load involved in certain points of the interaction. A conceptual proposal was made and analyzed using the Lightning decision jam tool [6] with the purpose of identifying opportunity areas for improvement and of prioritizing those solutions with the greatest positive impact on the user experience.

2.3 Conceptual Design

As mentioned before, general problems were detected and were refined into specific problems which were divided into detailed problems in order to aim for a solution. The next step was the directed conceptual design which consisted of proposing several solutions which can be viable or not. Later on, one of these solutions was chosen for the defined conceptual design; which lead the path for the final conceptual design. This stage was grounded on more creative viable ideas and ergonomic strategies applied into each zone previously described. Finally, the final conceptual design was sketched and approved by all the members of the team.

3 Results

Our redesign is focused in three main categories: tool simplification, ideal posture for the driver and user experience. These three categories can be applied in the four chosen sections of the tractor cabin., which are shown in Fig. 1 and will be described in the following sections.

Fig. 1. General views of the design proposal for the tractor's cabin interior with ergonomics adjustment in the driver's seat, multi-purpose accessory, joystick and frontal panel.

3.1 Driver's Seat

Literature review shows that tractor drivers lack good posture due to visibility matters, even though the main function of agriculture vehicles consists of moving forward and backward to an objective. The driving posture is affected by the cabin space arrangement, consequently increasing discomfort and injury risk (Haoyang, Dongwei, Xuechao, & Xiaoping, 2019). Being the main component in the cab, where the user takes most of its interaction, the backrest angles, percentiles, and pressure distribution provide a comfortable posture that allows the operator to perform tasks efficiently, maintaining a correct posture in which all joints must be between 90 to 120 degrees.

A seat is proposed quilted with uniformly flat medium type seat cushioning. It provides better stability and weight distribution through an extensive surface. It can reduce loads in the ischial tuberosity's that could lead to ischemia or interference in irrigation blood, causing pain and even numbness. It also proposes a 90 degrees' angle formed by the backrest and seat seeks to collect the spinal profile in the lower back, specifically the lumbar, to provide support in this section. Our proposal for the seat considers the user's movements involved: tilt movement, where its maximum angle of inclination is 30 degrees for the backrest, increasing the user's comfort, and vertical and horizontal, facilitating the user adjustments to accurate it with their measurements. It also contains an axis easing rotation inside the cabin 45 degrees on each side for a better reach to the other components. Besides, the two armrests can be moved up or down depending on user needs.

3.2 Multi-purpose Accessory

This space hosts comfort accessories to bring users more effectiveness while using them and working, aiming for an enjoyable laboring experience. It is commonly composed

of five sections, and our proposal design considers all of them as it follows. The storage area opens with a sliding door mechanism allowing the user to open or close rapidly. The front hollow considers the handgrip thickness and width specified by men 5 percentile, allowing better access to the area and bringing fast maneuvering. Next, to avoid spilling, accidents, or even burns caused by liquids. The adjustable drink holder guarantees better maneuvering throughout working hours. It adapts to the maximum and minimum diameter for the drink container. As a consequence of cabins usually lacking space, a push-open GPS screen allows better visibility by adjusting the height and reach to maintain a correct posture while operating. And, to ensure differences between tractor functions and commodity functions, it works through a touch screen.

3.3 Joystick

Physical and mental fatigue, as well as stress, are imposed upon the driver while driving [7]. The appliance of anthropometric dimensions and biomechanical gestures on tool simplification for the lever system and adjustments controls provide an accurate operator accommodation. Granting better reach, avoiding Kumar's overextension, and enhancing drivers productivity, comfort, and safety. Anthropometry relates to physical and individual human dimensions and is only meaningful if the worker's activities are also analyzed, meaning that biomechanics are involved too. As mentioned before, the overextension theory involves continuous holds of contractions, increasing injury risks. The suggestion is to maintain activities on the preferred work level (PWL), meaning gross motor efforts are under 40 percent of Model View Controller (MVC) and overestimate efforts greater than that value, maintaining the job risk-neutral. Three different operations gathered into a multifunctional joystick can decrease wrists and forearms musculoskeletal injuries. Replacing overextension and continuously holds with a better handgrip by using just thumbs force. Moreover, the armrest can adjust its height to connect with the joystick, providing a 90-degree angle between the upper arm and the forearm, resting the elbow and the wrist in a neutral position. And, maintaining hands between waist and shoulder height [8].

Joystick design depends on the optimal cylinder grasping with minimal joint torques in the fingers. This configuration will relate to the diameter to freely move the thumb and the other four fingers wrapped around the stick. Previous experiments have shown that the smaller the radius is, the larger joint displacements are concerning the neutral hand gesture. Therefore the suggested radius for the middle finger is between 15–20 mm and for the other fingers, smaller than 15 mm [9].

A new joystick design is proposed based on the movements are applied deppending on the user's purpose. In this case, a 2-axis joystick allows forward, backward, left, and right. Tilting for velocity adjustments and changing direction. And the buttons, organized by color-coding: blue for hydraulics, orange for engine and gearbox, yellow for power take-off, and white for headlights. Rapid identification of functions and feedback about the correct application of the elements was accomplished by the use of visibility and feedback, principles from Don Norman´s Interaction Design [10] that are ment to help the user by using pictogram tags, color, lighting scheme, and constraints.

3.4 Frontal Panel

The main operating functions of a frontal panel are the indicators, engine receptor, movement levers, tachometer, among others. After applying ergonomic adjustments, a frontal panel is proposed where the fuel gauge and the brakes illuminate with a light scheme to ease visual contact with each level indicator (e.g. activated, deactivated), resulting in lessening distractions while driving. Two levers were simplified; the first one controls the basic movements; for example, drive, reverse, and neutral. The additional lever includes specific functions; as the 4X4, the Independent Power Take-off (IPT), and the Dependent Power Take-off (DPT). These functions are shown on the screen next to each lever to indicate the driver the selected operation. In addition, every time the screen lights on with a new warning it emits a sound to get the driver's attention. If the warning signal involves immediate danger to the driver (a flat tire, low gas, engine overheating, etc.) it should remain sparkling and emitting sound until the problem is attended to. Finally, the tachometer, the temperature gauge, and the symbols or pictograms on the dashboard are clear and visible.

4 Discussion

Attending ISO and SAE norms, the redesign was based on comfort, safety, and productivity for the user in a standard tractor cabin.

According to Norm ISO 26322-1, which specifies general safety requirements and their verification for the design and construction of standard tractors used in agriculture and forestry, these standard tractors have at least two axles for pneumatic-tired wheels, with the smallest track gauge of the rear axle exceeding 1 150 mm, or tracks instead of wheels, with their unballasted tractor mass being greater than 600 kg. In addition, this part of ISO 26322-1 specifies the type of information on safe working practices (including residual risks) to be provided by the manufacturer, as well as technical means for improving the degree of personal safety of the operator and others involved in a tractor's normal operation, maintenance and use. It is not applicable to vibration or braking [11].

Ergonomics takes an important place in this matter, by making all designs suitable to a major quantity of users, and reducing physical fatigue, as well as short or long term injuries. A requirement established in the norm ISO 4254-1, is to provide the driver a system that permits to simultaneously use two hands and a foot or two feet and one hand when boarding, or dismounting from, a machine [12]. This three-point contact support allows the user to be regarded as a part of a vibro-acoustic system coupled via the contact points steering wheel, seat, floor panel and pedals with the vehicle, a coupled person-machine system [13].

The reach is defined for hands by a sphere of 1 000 mm radius, centered on the seat centered, 60 mm in front of and 580 mm above the seat index point (SIP) as defined in ISO 5353 and for feet by a hemisphere of 800 mm radius, centered on the seat centered at the front edge of the cushion and extending downwards, with the seat in its central position (Fig. 2).

Anthropometry information percentile was taken into consideration, 5 and 95, even though cabin dimensions make a challenge to suit accessories and other elements due to

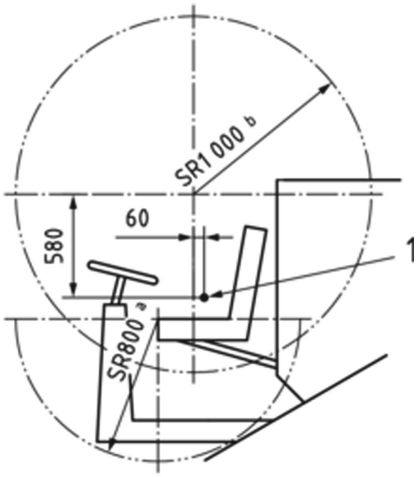

Fig. 2. Hand and foot reach defined in ISO 4254-1.

its small workspace. The cultural recognition and human factors involving the agriculture system were the basis to give users proper adaptation and good management of a tractor as their daily work tool.

A next step for complementing this project and validating the correct implementation of the adjustments we're proposing should be a usability test with real users, which couldn't be achieved in this first stage due to the COVID-19 Pandemic restrictions.

5 Conclusion

Tractor cabins should consider the variability of user needs and limitations regarding their safety and comfort to avoid musculoskeletal injuries and long-term health damage. The design is grounded in Ergonomics. Beneficiating the outcomes which optimize the drivers' well-being and overall system performance. The methodologies applied for recognizing the main interaction issues and for achieving a specific design proposal have been proved to make a positive impact on the tractor's usability and the operator's experience since they provide the new design with physiological, anthropometric, and biomechanical adjustments. While investigating actual proposals and ergonomic approaches to transportation design, problems were prioritized and analyzed in order to adapt our concept to the user's health and satisfaction. Using symbols and other culturally recognized elements, aside from regulated standards, the user can exercise better usability, faster interpretation, better use of tools, and performance in their work.

References

1. Haoyang, L., Dongwei, Z., Xuechao, M., Xiaoping, J.: Predictive model of tractor driving posture considering front and rear view. Biosyst. Eng. **185**(1), 64–75 (2019)

2. International Ergonomics Association: Human Factors/Ergonomics for a better life for everyone (2020). https://iea.cc/
3. Kuta, L., Stopa, R., Szyjewicz, D., Komarnicki, P.: Determination of comfortable position for tractor driver's hands based on dynamic load. Int. J. Ind. Ergon. **74**, 102866 (2019)
4. Human Factors and Ergonomics: ACF Design Technology (2021). https://acfdesigntech.pbworks.com/w/file/fetch/103526039/Topic%201%20Overview%20Part%202.pdf
5. Evans, N.: Destroying collaboration and knowledge sharing in the workplace: a reverse brainstorming approach. Knowl. Manag. Res. Pract. **10**(2), 175–187 (2012)
6. Courtney, J.: Lightning design jams: the exercise that will solve all your problems (2018). https://www.invisionapp.com/inside-design/lighting-design-jams
7. Hegazy, R.: Ergonomic studies on controls layout, drivers anthropometric and noise exposure for Egyptian farm tractors. Farm Mach. Power **28**, 898–916 (2011)
8. Jaques, E., Grants, H.: Work simplification and Ergonomics can relieve pain (2020). https://www.verywellhealth.com/what-is-work-simplification-2564436
9. Peña-Pitarch, E., Yang, J., Abdel-Malek, K., Kim, J., Marler, R.: Joystick ergonomic study in material handling using virtual humans. In: American Society of Mechanical Engineers, Manufacturing Engineering Division, MED (2005)
10. Norman, D.A.: The Design of Everyday Things. Doubleday, New York (1990)
11. I.O.f.S. ISO: «Tractors for agriculture and forestry - Safety - Part 1: Standard tractors (ISO 26322-1)» (2008)
12. I.O.S. ISO: «Agricultural machinery - Safety - Part 1: General requirements (ISO 4254-1)» (2013)
13. Genuit, K.: «Vehicle interior noise: a combination of sound, vibration and interactivity», pp. 1025–1035 (2008)