

A Relationship Between Design and Drivers' Discomfort Perception in Baja SAE Competition Vehicles

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Keywords: vehicles' design, vehicles' ergonomics, comfort

1 Context

The present study is part of a research project to assess the ergonomic conditions of two vehicle designs used in the Baja SAE students' competition: the previous design concept, created in 2013 and, the new one, created in 2015. The next pages summarises a study that focused on the relationship between design and comfort among pilots of both cars. It aimed to provide design guidelines for the next concept (under development), in order to improve ergonomics aspects and consequently the comfort of pilots while driving the vehicle.

Besides the mechanics, the main design differences between both cars are the following:

- total length and chassis length respectively: 1959mm and 1400mm in the 2015 concept; 1930mm and 1445mm in the 2013 concept;
- the driver's seat was totally redesigned in the 2015 model. A thin shape of the seat, a backrest with headrest and decreased dimensions were adopted in the 2015 concept; whilst the 2013 had a shell shape and wider dimensions of the length of the seat and the width of the backrest.

Several past studies in vehicles' ergonomics and comfort, focus on seats' comfort (ZENK, 2012; KAMP, 2012; VINK *et al.*, 2012; HOFFMAN and JUNIOR, 2010; FAI *et al.*, 2007; KOLICH *et al.*, 2004; KOLICH, 2003) and drivers' posture (HANSON, 2006; PARK *et al.*, 2000, PORTER and GYI, 1998; TILLY e DREIFUSS, 1993; REBIFFE, 1969). They recommend adjustable mechanisms in the drivers' seat, backrest, headrest, steering wheel, and other controls, allowing that the drivers' position is safe and comfortable for a great diversity of people (generally from the 5% to the 95% percentile of the population). Other studies recommend seats' shape and

materials that support the body shape, thigh, and spine comfortably, distributing the weight and pressure in the lumbar.

The present study analyses the design factors that are directly related to the discomfort and lumbar pain reported by the pilots of the vehicles, detailed in a previous study (ZITKUS *et al.*, 2016). Based on their responses added to postural analyses, the two vehicles (2015 and 2013) were compared in terms of their designs and the discomfort perceived by the conductors.

2 Methods

To test both vehicles, a track was chosen based on the characteristics of the terrain and its extension, emulating the race track. Fourteen participants tested the vehicles, all of them experienced pilots involved in the project of the 2015 concept.

All participants signed a consent form before taking part in the study. Then, they completed a questionnaire which encompasses three sections:

- 1) personal data, such as age, height, weight, whether the participants have any injured muscle or whether they are under health treatment;
- 2) a discomfort questionnaire with a body diagram divided into 18 areas and a discomfort scale from 1 to 5 (none to extremely uncomfortable, respectively) to be filled before the test, and;
- 3) the same discomfort questionnaire to be filled after the test.

In addition to the questionnaire, the posture of the lowest and the highest stature pilots were recorded to evaluate their driving posture. The freely available software SAPO (SOUZA *et al.*, 2011) was used to measure and analyse their postures. The results were cross- compared with the responses to the questionnaire.

3 Results and Discussion

The results indicate that the 2013 concept was perceived as more comfortable than the 2015 concept. According to the pilots the major discomfort problem was in their back. After testing the 2013 concept, they registered lower discomfort in the lumbar, whilst in the test with the 2015 vehicle, they recorded high level of discomfort in various areas of their back. Other five body areas classified as lower or moderate discomfort in the 2013 model, were classified as extremely uncomfortable in the 2015 model.

The perceived discomfort was compared to the postural analysis, and three ergonomic problem were clearly identified:

- the discrepancy of the postural angle recommended in the literature and the one measured between the thigh and back of the tall and short pilots in the 2015 concept;
- the space reduction in the cockpit in the new model (2015), changed the seat and pedals position, which affected the posture of the pilots whose legs were flexed all the time;

- the seat changed in the new model, and the posture is closed to right angle in the seating position, which pressures the lumbar, becoming more sensible to the impacts of the irregular terrain where the tests and races happen. Additionally, the seat dimensions were reduced and the thighs are not supported; and the cushion thickness reduced.

4 Conclusions

This study analysed some of the factors that cause discomfort in BAJA SAE vehicles. Although the comparative analysis was based in only two cars, the design differences between them were significant, with great impact in the ergonomics of the new vehicle. The 2015 concept have design elements that restricted movements; modified the posture of the pilot, decreasing the distribution of the pressure in the back and overloading the lumbar; and, lacked support for the thigh. All these factors together affected the pilots, and as a result of which they reported extreme discomfort in some body regions, specially in the back.

The study ends by suggesting design changes to be implemented in the 2017 model, three of them are: a shape of the seat that adapts to the natural curve of the lumbar spine; a seat's back that reclines and augment the support to back pressures; and, a seat cushion in a shell shape with enough room to support the thighs. These design recommendations aim to enhance the next model, in order to enable the team involved in the next BAJA SAE to balance the performance of the vehicle with a more ergonomic design.

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6 Acknowledgments

We would like to acknowledge the research funding body CAPES - Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - and to thank all the pilots participants in this study and members of the PAC BAJA SAE - Unesp, Bauru.