

ERGONOMY OF THE INSIDE OF A MOTORCAR CABIN USED BY A PERSON WITH LOCOMOTIVE DISABILITY– A CASE STUDY INVESTIGATIONS OF THE SUBJECTIVE DISCOMFORT SENSATION

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Abstract

The study presents results of investigations carried out in the course of driving a motorcar by a person with a locomotive disability. Driving tests were conducted in road conditions. The scope of the performed analysis covered investigations concerning somatic and receptor relationships in the man – technical means system and, to a lesser extent, dealt with the psychological aspects of vehicle driving. The investigations employed selected methods of identification of expectations from direct users – questionnaire and interview. Initial investigations were carried out for one person with a locomotive disability (paraplegia). The authors used tests for the determination of subjective sensations during motorcar driving (comfort test and seat comfort). The employed questionnaire tools used verbal and point scales. The final result of initial experiments is a description of the adjustment of the vehicle with equipment (manually-operated accelerator – brake device) to the requirements of the driver with a locomotive disability on the basis of the driver's subjective sensations of discomfort. This type of information obtained in the form meeting the wishes or demands of the user provides the basis for the elaboration of design requirements. The results indicate that a typical driver's space designed for an able-bodied person does not fully meet the requirements of a person with a locomotive disability.

Keywords: *personal car, a driver with a locomotive disability, questionnaire examination, interviews, discomfort*

1. Introduction

The technical process of car designing is usually focused on technical requirements and stylistics rather than on the ergonomic quality of the vehicle inside. Ergonomic requirements are difficult to specify precisely, the main reasons being: considerable variability of somatic as well as receptor characteristics among the users' population, changing psychological sensations, perception of comfort etc. This leads to the need of developing complex families of technical objects. Their modification to suit individual characters is possible thanks to the application of regulated adjustments or designing for territorially or individually confined groups of persons in different populations (e.g. designing for the needs of European or American markets).

Designing processes and analyses should be based on: requirements concerning minimal fatigue, sensation of comfort and safety in combination with changes occurring during journey. When investigating the well-being of a driver, it is important to pay attention to his/her subjective feelings of comfort.

Discomfort may have a number of different sources: (1) may be caused by movement or lack of movement, (2) may be temporary or continuous, (3) may stem from psychological, and may not stem physical sensations. The degree of discomfort may be assessed using point scores which refer to the user’s subjective psycho-physical sensations. The degree of the complexity of an activity or feeling of comfort is evaluated individually. Point scores are frequently employed when we want to diagnose a man’s loading during a process of carrying out a labour activity [1], when assessing pain [4] or noise arduousness [3]. Ergonomic assessments are based on measurements of energetic expenditures (assumed labour positions, performed activities, values of muscle forces and number of repetitions connected with movement monotypic nature). The assessment of discomfort depends on the user’s subjective, individual perception and, therefore, investigations should be repeated several times in order to objectify them.

Investigations of the process of car driving can be carried out in simulators or in a real environment. The construction of true models (life-size mock-ups) representing vehicle insides frequently fails to provide comprehensive information about the true behaviour of the system on the road (e.g. information about fatigue). On the other hand, it should be said that models are definitely more reliable in comparison with computer simulations. The research results presented below were obtained during tests carried out in road conditions.

2. Investigations of comfort sensation

The test was conducted at the same setting of the driver’s seat. The objective was to check if the set position was appropriate taking into consideration the access to comfort zones. The initial position should be balanced (regulations carried out by the user resulting in the achievement of the most comfortable position) ensuring comfort.

Investigations were carried out for selected subassemblies of the cabin of the car. The body support system is particularly important, in this regard. The subassemblies which make up the zone of interactions [4] man – technical means in the car comprise: car floor, seat, steering wheel, accelerator-brake manual device. In the course of the performed experiments, special attention was paid to the analysis of the driver’s seat geometry.

2.1. Investigations of the body support zone

Investigations of the support zone were carried out for the driver-seat interaction (Fig. 1) using a questionnaire method in the course of driving a distance of 140 km for the period of 2 hours and 45 minutes (answers in the first column), after 1.5 hours’ break and in the course of another 2 hours 45 minutes driving of 140 km (second column, Fig. 1).

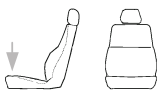
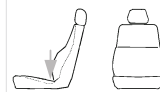
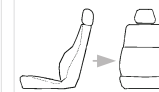
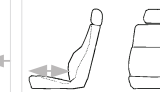
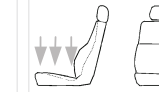
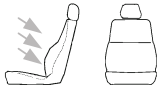
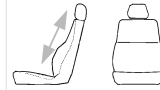
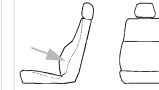
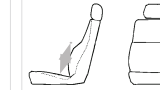
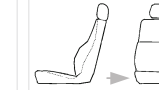
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Other remarks (describe with your own words):no remarks.....				

Fig. 1. Questionnaire – driver’s seat geometry

Prompts placed under pictures of potentials occurrences of discomforts or their causes were meant to help the respondent’s selection of possible inconveniences. Some space was also left for additional remarks.

2.2. Subjective sensation of discomfort in the course of driving

Similarly to the terminology employed in medicine, the degree of discomfort studied during driving can be determined employing one of three scales: visual-analogue, verbal or numerical. In this study, the authors used the numeric system.

A 5-point scale was applied (Fig. 2) using the following designations: 0 – no feeling of discomfort, 1 – slight discomfort, 2 – moderate discomfort, 3 – significant discomfort, 4 – maximal discomfort.

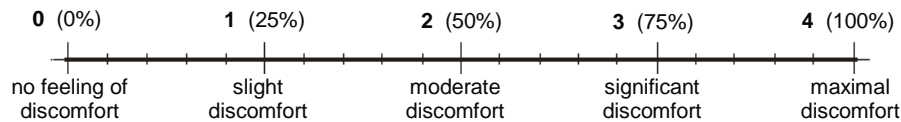


Fig. 2. Scale of discomfort employed in this study

Simultaneously, point values are supplemented by verbal comments (degree of intensity of discomfort sensation) which allow the pollster to communicate with the respondent. The verbal format is intended as a prompt. As in methods assessing pain intensity (e.g. Visual Analogue Scale (VAS) method) [4], a simple description of discomfort affects the ease with which the driver answers questions. The applied value: 0 (less than 25% of the maximal value – in the considered case 4) indicates good adjustment; vales 3 and 4 (more than 75% of the value) – bad adjustment and the need to do something about it. Intermediate values are acceptable, although they require detailed consideration in order to eliminate discomfort. Discomfort investigations lead to the identification of factors affecting the quality of adjustment (technical means – driver) and the alleviation of the arduousness of performing an activity during driving.

The driver's discomfort diagram (Fig. 3) was filled as soon as the driver assumed his position in the car as well as in the 15th, 45th, 105th, 135th and 165th minutes of driving.

Duration of investigations	0min	15min	45min	1h 15min	1h 45min	2h 15min	2h 45min
NECK	0; 0	0; 0	0; 0	0; 1	0; 1	0; 1	1; 1
UPPER PART OF THE BACK	0; 0	0; 0	0; 0	0; 1	0; 1	1; 2	1; 1
LEFT SHOULDER	0; 0	0; 0	0; 0	0; 0	0; 0	0; 0	0; 1
RIGHT SHOULDER	0; 1	0; 1	0; 1	0; 1	0; 1	1; 0	0; 2
CTR. & LOWER BACK	0; 0	0; 0	0; 0	1; 1	1; 2	1; 2	2; 3
LEFT FOREARM	0; 0	0; 0	0; 0	0; 0	0; 0	0; 0	0; 0
RIGHT FOREARM	0; 0	0; 0	0; 0	0; 0	0; 0	0; 0	0; 0
CHEST	0; 0	0; 0	0; 1	0; 1	1; 1	1; 2	1; 1
ABDOMEN	0; 0	0; 0	0; 0	0; 1	0; 1	1; 1	1; 1
LEFT HAND	0; 1	0; 0	1; 2	2; 3	3; 3	3; 3	3; 2
RIGHT HAND	0; 0	0; 0	1; 1	1; 1	2; 2	1; 2	1; 1
LEFT ARM	0; 0	0; 0	0; 0	0; 0	0; 0	0; 0	0; 0
RIGHT ARM	0; 0	0; 0	0; 0	0; 0	0; 0	0; 0	0; 0
LEFT ELBOW	0; 2	1; 2	1; 2	2; 4	3; 4	3; 4	4; 4
RIGHT ELBOW	0; 0	0; 0	0; 0	0; 0	0; 1	1; 1	0; 1
LEFT BUTTOCK	1; 0	1; 0	2; 1	2; 0	2; 2	2; 4	3; 3
RIGHT BUTTOCK	1; 0	1; 0	2; 0	2; 0	2; 2	2; 4	3; 3
LEFT THIGHT	0; 0	0; 0	1; 0	1; 1	1; 2	2; 3	2; 3
RIGHT THIGHT	0; 0	0; 0	1; 0	1; 1	1; 2	2; 3	2; 3
LEFT KNEE	0; 0	0; 0	0; 0	0; 0	0; 0	0; 1	0; 0
RIGHT KNEE	0; 0	0; 0	0; 0	0; 0	0; 0	0; 1	0; 0
LEFT CALF	0; 0	0; 0	0; 0	0; 0	0; 0	0; 0	0; 0
RIGHT CALF	0; 0	0; 0	0; 0	0; 0	0; 0	0; 0	0; 0
LEFT FOOT & ANKLE	0; 0	0; 0	0; 0	0; 1	0; 0	1; 1	1; 1
RIGHT FOOT & ANKLE	1; 0	1; 0	0; 0	0; 1	0; 0	1; 1	1; 1

Fig. 3. Diagram of the driver's discomfort

The driving test was performed twice. Point values given in column 1 (at each time interval) give the results of measurements taken during the first 2 hours and 45 minutes of driving the distance of 140 km. Values listed in the second column give test results carried out 1.5 hours after the first test as well as during 2 hours and 45 minutes driving of 140 km distance. Selected values were highlighted (grey fields in the table) in order to indicate places and times of discomfort occurrence. Additionally, results indicating the appearance of considerable discomfort were marked with bold type.

3. Conclusions

Analysing the obtained results collated in Figures 1 and 3, the identified problems can be divided into two groups.

The first group includes the discomfort associated with the maladjustment of the driver's seat which fails to ensure appropriate distribution of pressures in the seat-driver zone. It was in this area (thighs and buttocks) that the worst discomfort was felt. The symmetry of discomfort indicates that there is no need to apply asymmetric seats (with independent support regulation of the right and left thigh). In addition, a person with a locomotive disability, in comparison with an able-bodied person, has distinctly fewer possibilities of changing the position on the seat when driving (mean discomfort score of buttocks – 1.6).

The second group of problems is associated with the requirement to steer the car with the assistance of the left hand and with a smaller trunk stability of the disabled driver in comparison with an able-bodied driver. The considerable load of the left hand resulted in the mean score of about 1.9. In conditions of road driving, it is necessary to counteract gravity forces. In the examined case, the driver used primarily the upper limbs for this purpose which resulted in a distinct reduction of the experienced comfort in the left elbow (mean score – 2.6). A discomfort was also reported in the area of the upper back (the cervical part of the spinal column) as well as a significant discomfort in the middle and lower part of the back (lumbar and thoracic parts), especially in the second stage of driving. A gradually increasing discomfort of the chest also appeared. The cause of this discomfort was the compression on the chest by the seat belt. A significant value of the discomfort was also observed for the right shoulder (during the second stage of driving).

It will probably be possible to improve the driver's comfort by:

- Changes in mutual arrangements of subassemblies inside the car cabin,
- A changes in the stiffness and position of the body support (a support for the left elbow similar to the standard armrest for the gearbox manipulation),
- Ensuring greater trunk stability (e.g. seats of different geometry, a different construction of seat belts).

The result analyses of the performed questionnaires clearly indicate that a typical driver's space designed for an able-bodied person does not fully meet the requirements of a person with a locomotive disability.

The performed initial investigations allowed the authors to obtain from the user indirect information which may be very useful to prepare precise requirements for the process of redesigning of assistive technology. The ultimate objective of the performed investigations was to elaborate specific design recommendations and their utilisation in the process of adaptation of vehicles for the needs of persons with locomotive disabilities.

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