

ACTIVITY AND EYE MOVEMENT ANALYSIS AS BASIS OF VEHICLE CABIN DESIGN

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An inventory of different methods was developed over the last couple years to evaluate the ergonomic quality of different drivers workplaces. The cockpit of short-haul buses, long-haul buses, streetcars and harvesting machinery were evaluated. Based on this analysis criteria for the re-design could be developed. E.g. the design of the standard German short-haul buses is based on the results of such an analysis. In a first step, the physical layout of the cabin is recorded and evaluated. The analysis of the (static) posture of a large number of different subjects in a number of typical positions gives valuable information about the anthropometric design of the workplace. It is complemented by an analysis of the posture during the real task with a smaller number of subjects. In addition, the activities and the eye movements of the subjects during the real task are recorded and analyzed and used as input for the re-design of the cabins.

INTRODUCTION

The design of the drivers workplace is of outmost importance for the safe and secure operation of all kinds of vehicles. It is necessary to ensure the safe operation of the vehicle so that no other persons or things are endangered. This implies that the workplace is designed in appropriate ways. But the safety and health of the driver must also be in the focus while designing the cabin.

Figure 1 lists, as an example for a driving task, some of the demands adding to the workload of coach drivers.

- **Driving task**
- **Additional tasks**
- **Environmental factors (e.g. noise, climate)**
- **Unusual working hours**
- **Time pressure**
- **Responsibility**
- **Poor workplace design**
- **Monotony**
- **Communication**
- **Social factors**

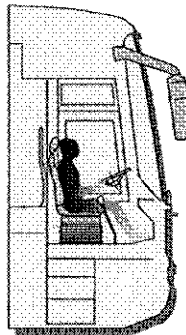


Fig. 1: Some of the demands adding to the workload of coach drivers

In the last years the Institute of Industrial Engineering and Ergonomics at Aachen University of Technology was asked by different institutions and companies to evaluate and design drivers workplaces for different kinds of vehicles. These included streetcars (Göbel, 1999), short-haul busses (Göbel et al., 1998) and coaches (Lohse et al., 1998), as well as combine harvesters. Doing so, an inventory of methods was developed and refined. The different elements will be introduced and illustrated with results from the various studies.

INVENTORY OF METHODS

The inventory of methods follows a systems approach. It is organized according to an incremental broadening of the system border and time perspective. As a first step, the "static" requirements of the drivers workplace are analyzed. The physical dimensions of the workplace are acquired and contrasted to the anthropometric requirements of the driver in fulfilling the driving task and additional tasks.

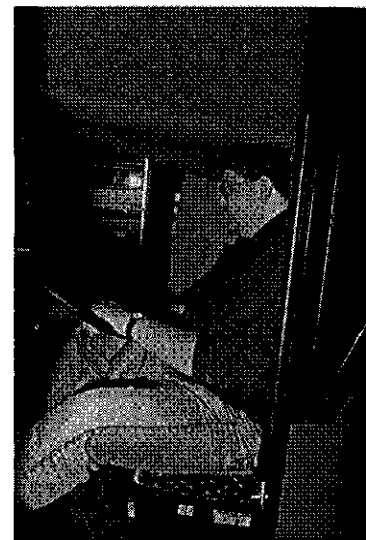


Fig. 2: An obvious example for a misfit between the driver and his workplace

In a second step, the interaction of the driver with the workplace is looked at during real task execution. In other words, the perspective is broadened in the time dimension similar to the difference between a "still picture" and a "movie".

For the third step, the system border is widened to include the physical environment. A video based task analysis is performed and information intake and processing requirements are evaluated with the help of an eye movement analysis.

In addition to these analyzing steps it was found very worthwhile to use a questionnaire to gather additional information from a greater driver population.

Physical layout and static analysis of posture

Only in a few cases are the shortcomings of the anthropometric design of a workplace as obvious as shown in figure 2. The analysis of the physical layout is one basic building block for an ergonomic evaluation of the workplace. The analysis can be done on the basis of drawings, if they are available. But it is always advisable to refer to a vehicles "in use" to check, if the drawings are in accordance with the "real" vehicle, if any additional equipment has been build in or certain space is needed or usually used to store things, e.g. a drivers briefcase. In addition, some measurements are difficult to take from drawings e.g. the narrowest part in an access way.

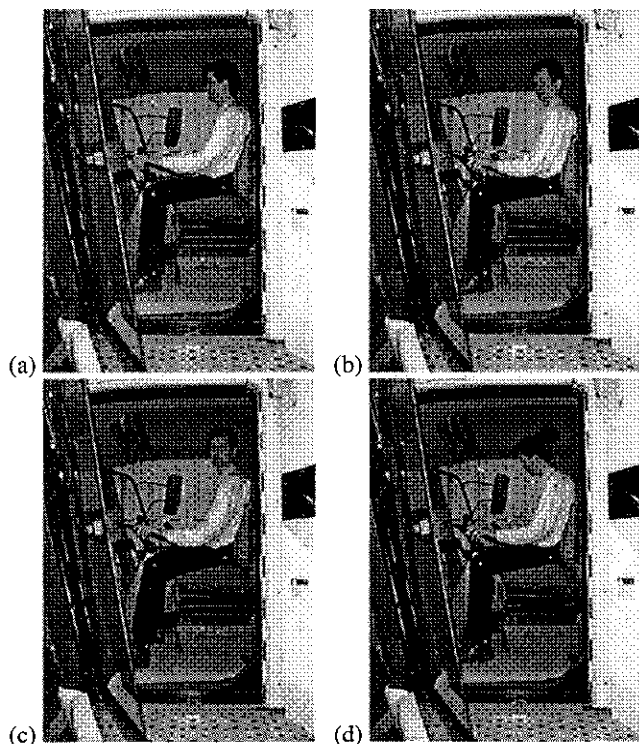


Fig. 3: Analysis of static posture in a combine harvester: The person was asked to take the position for (a) normal driving while harvesting, (b) looking at the cutterbar, (c) unloading the grain tank, and (d) shifting gear

The great variability of people and their preferences in positioning the different adjustable elements of the workplace can only be captured if a greater number of persons is analyzed. This is hardly ever possible during real driving situations. Therefore the static posture of a greater number of persons is recorded and evaluated. The persons for the "static" measurement should be representative for the driver popula-

tion of the particular vehicle and have some knowledge of the task. It is not required that they are actual drivers.

Prior to the recording of the body postures, the person is acquainted with the task and asked for necessary personal data. It is advisable to bring the seat and other adjustable elements of the workplace in an obviously unfit position. All possibilities for adjustments should be pointed out to the person. The major joints of the person are marked with contrasting self-adhesive points. The person is asked to assume typical postures (see figure 3) and photographs are taken.

The position of the adjustable elements and positions and angles of the body are later determined with appropriate software or manually. The angles for head, trunk, hip, femoral and knee are naturally varying for the different persons. But the angles are physiologically independent from body size. The so obtained angles of the body are plotted over body heights and compared with reference data (figure 4).

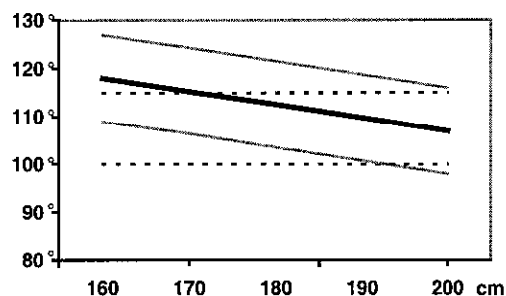


Fig. 4: The linear regression of hip angle (black solid line) over body height (48 bus drivers in 11 different types of coaches). Gray lines denote 90% variance interval. The area between the dotted lines denotes the recommended hip angle. Only large drivers hip angles are fully in the recommended range, smaller drivers have in tendency too splayed hip angle

The results of the "static" analysis of the body posture can later be compared with the "dynamic" postures recorded during real driving.

Dynamic analysis of posture

For a smaller group of drivers an analysis of the posture can be done during real driving tasks. Similar to the static analysis, the driver is asked to adjust the seat and the body joints are marked with self adhesive points. A video or digital camera is used to record the body position over time. The data are analyzed for a sample taken every second minute.

Figure 5 shows as an example the results for a coach driver for a 3 hour period. Over the time the posture becomes more "slumped". When redesigning the drivers workplace the seating position, and all factors affecting it, should be considered with special attention.

In addition, the posture while performing certain sub tasks is recorded too. For example, during coach driving the reaching for the microphone, the operation of the radio or the sun shade could imply unfavorable body postures.

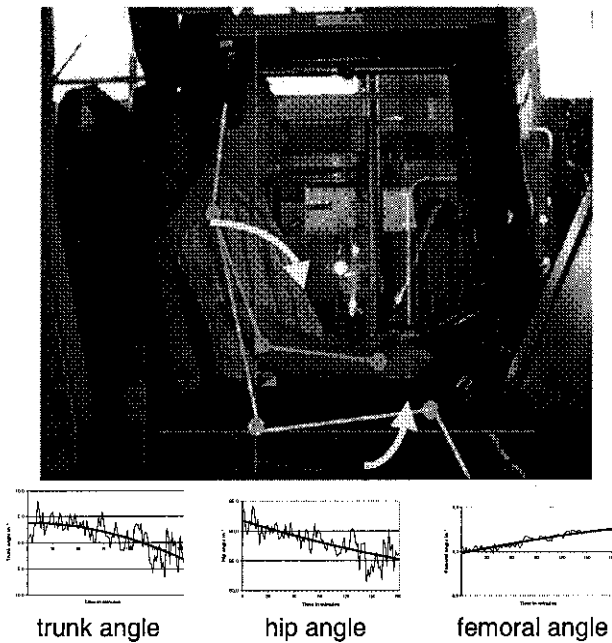


Fig. 5: Variation of trunk, hip and femoral angle for one bus driver over a 3 hour driving period (vertical lines at 5° intervals). Clearly the more “slumped” posture at after about 2 hours can be seen.

Task analysis

For the task analysis the vehicle is equipped with one or more video cameras. The cameras should be positioned in such a way that the actions of the driver and the relevant elements of the physical environment, e.g. traffic situation, can be recorded.

For the different vehicles between 8 and 11 drivers were asked to perform typical tasks for the analysis. With a total task time of typically 18 hours or more, results can be deducted with confidence. The route and/or task should be standardized. If this is not possible, at least a classification of the different elements of the route/task should be done.

The task analysis is accompanied by the recording of physiological parameters (e.g. ECG, heart rate variability) to identify especially straining tasks. The procedure is described in detail in Göbel et al. (1998). In addition, a subjective workload rating can be administered (e.g. the modified BLV Test, Bronner & Karger, 1985).

The time-stamped video data are analyzed with the help of a semi-manual encoding software. For every type of vehicle the software allows the definition of a set of hierarchical items. Figure 6 shows as an illustration the hierarchy of the items for the combine harvester study. For the bus driving studies the items were defined for the driving state and for primary tasks (necessary for safe driving) and secondary tasks (all other tasks). Timelines are generated for all items. Based on those timelines, the frequency, the duration and the order of actions were scored. In addition, the simultaneous occurrence of items at the different levels can be analyzed.

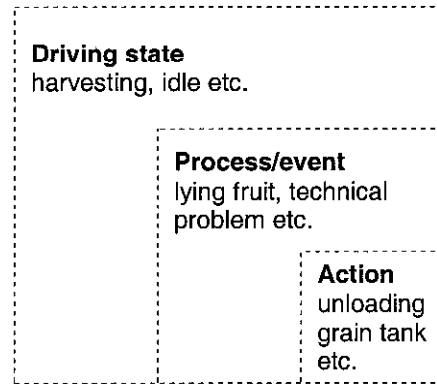


Fig. 6: Hierarchical structure of items to analyze the task of a combine harvester driver

The results for the short-haul bus study are reported in Göbel et al. (1998). Some additional data for the coach study and the combine harvester study can be seen in table 1.

Tab. 1: Percentage of driving and waiting times for the two bus studies and the respective times for the combine harvester (only times on the field were analyzed)

	driving	waiting	
short haul bus	57.0%	29.1%	
coach	91.3%	8.7	
	threshing	idle	break
combine harvester	74.5%	20.2%	5.3%

Another result of the task analysis was used to evaluate the layout of the combine harvester interior design. The switch console is divided into two parts, one a little closer to the driver, the other a little further away. The analysis of all the operations of the switch console showed 63.5% of the operations on the inner console and merely 36.5% on the outer console, confirming the original design.

The knowledge from a task analysis is valuable as a basis for the redesign of drivers workplaces. The relative time spend for certain actions or interactions with the interface, the duration of actions, their frequency and the sequence of different actions are factors that should influence the layout of the drivers workplace.

Eye movement analysis

Visual information acquisition is assumed to be the major information source during (bus) driving, operating a combine harvester and other similar vehicles. Owing to the high visual information density to be processed even small attention and perception deficits may cause serious risks. To obtain information about the requirements for visual information acquisition, eye movement analyses are performed. All measurements were performed with the eye movement recorder NAC EMR-600. The NAC EMR-600 is a head-mounted device utilizing the cornea-reflex (see e.g. Rötting, 1999) to measure eye movements. After the device is individually calibrated an accuracy of about 1° can be achieved in field conditions. The

procedure is described in greater detail in Göbel (1999), Göbel et al. (1998) and Rötting et al. (1999).

Figure 7 and 8 show the distribution of eye movements to different parts of the vehicle and the surrounding environment while driving a coach and a combine harvester. Even though the tasks are very different, on a global level the eye movements are quite similar: for the coach 90% of the time is spent observing the road, for the combine harvester the value is 80.3% (cutter bar plus other outside views). The value for a short haul bus is 81.6% (Göbel et al., 1998). The time spent observing the mirrors is, as one would expect, largest for the short haul bus with 10.2%, followed by the coach with 2% and a low 0.75% for the combine harvester. 8.2% of the time driving a short haul bus, the gaze is directed to the cockpit instruments and customer service objects. For the coach the respective value is 5% and for the harvester 6.75%.

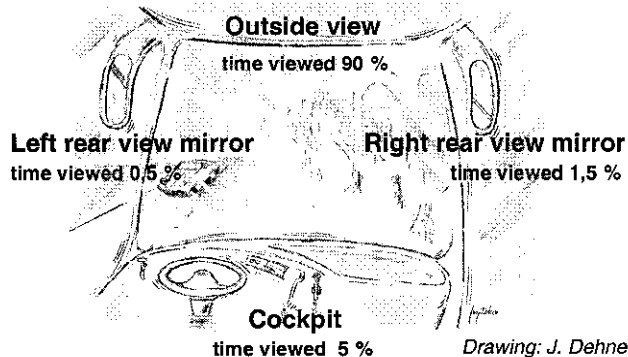


Fig. 7: Eye movement data for coach driving

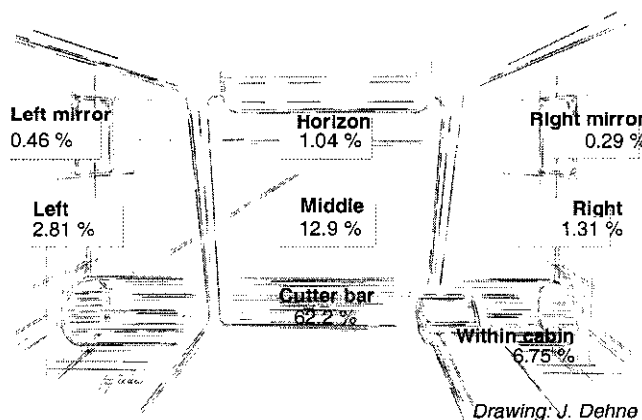


Fig. 8: Eye movement data for a combine harvester. The values are percentage of time viewed

CONCLUSION

The inventory of methods described here is a proven way to evaluate the ergonomics of drivers workplaces. Basic shortcomings of the workplace are identified by the analysis of the physical layout. The great variety of users can be considered with the analysis of static posture. Alone, this would not be enough, because the effects of time on task and the dynamic

interaction with the vehicle would be ignored. Therefore the analysis of the dynamic posture is needed, but now a smaller number of persons suffices. Essential for the evaluation and the design is the knowledge about the user tasks. An analysis of eye movements makes information acquisition observable.

The design of the cockpit of the new German standard short-haul bus has received substantial input from an ergonomic analysis using the methods described (conf. Göbel et al., 1998).

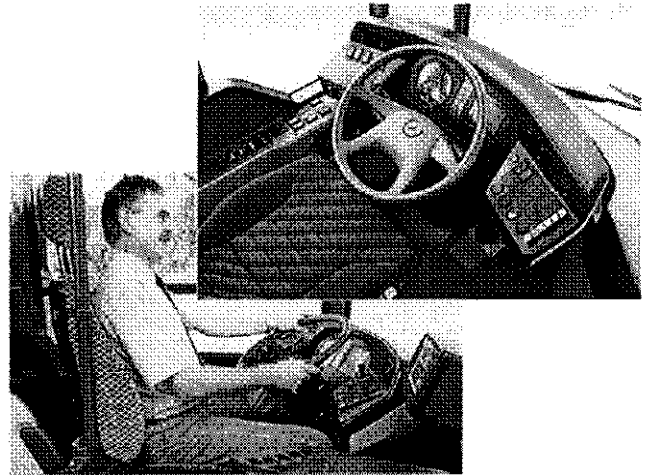


Fig. 9: Cockpit of the new German standard short-haul bus (Photographs: Daimler Benz)

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