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Truck drivers' postural and visual behavior An explorative study to understand expectations on current designs and future vehicles

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Abstract

After several decades of small incremental improvements, the development of ergonomics in truck driving environments is now facing a potential change with the introduction of autonomous driving. The knowledge on what happens to the driver's posture and vision related behaviour with an increasing level of automated driving is still very limited. The aim of this paper is to understand truck drivers' expectations on both current vehicles and future trucks with an expected increased level of automation, and to see how the expectations relate to previous driving posture related research. Truck drivers' postural behaviour is determined by several contextual factors. Some are related to the actual driving task and traffic situation, and some related to the cabin layout. Individual variability also largely affects the choice of sitting posture. The field of vision is often prioritized over sitting comfort in increasingly complex driving environments and drivers tend to adapt to a more forward leaning posture to get a better overview in these situations. An increased level of automation could potentially allow drivers to get an increased freedom in choosing their preferred postures but also possibly mean a change in their working tasks, with increased possibilities of performing secondary working tasks like transport planning and handling orders. However, the interviewees in this study generally imagined increased opportunities of finding relaxing and comfortable sitting opportunities rather than a change in the working task as a result of increased automation.

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1. Introduction

After several decades of small incremental improvements, the development of ergonomics in truck driving environments is now facing a potential change with the introduction of autonomous driving. However, the knowledge on what happens to posture and vision related behaviour with an increasing level of automated driving is limited. Variability in both human perception and behaviour has previously not been as commonly considered as anthropometric variability, but may be equally or even more important when automated driving is introduced. Increased automation will result in less control for the drivers [1], and a decreased need of instant access to controls inside the cab. Less control of the driving task would increase the possibilities of freely positioning the body in order to achieve desired comfort and visibility. Previous research shows how drivers with the same body dimensions tend to drive with considerably different postures [2-4], and increased freedom in positioning the body will probably also increase the possibilities of adopting different postures.

The increase of modern technology in current driving environment setups is making the work environment cognitively challenging [5] and drivers are required to handle the rapid changes between keeping eyes on both the traffic environment and in-vehicle systems, whose functionality and importance may vary greatly between different transport tasks. Increased automation is expected to decrease the cognitive load on the drivers [6] and this may change the drivers' requirements on the driver position layout. Each unique transport operation can create different requirements for each specific driver, and the challenge of accommodating specific requirements depending on variability in personal preferences and variability in transport tasks is not only an issue for future development. In current designs, including SAE automation levels 0-2 [7] with no or partial automation, there are few notable differences between driver position layouts for different transport segments. As an example, long haul driving and urban distribution are two rather diverse transport segments with their respective challenges, but the cockpit layout is very similar in the trucks used for these different transport types. There are also indications that drivers adapt different postural behaviour depending on the driving task [8;9], and this may imply that there should be more notable differences between truck driving layouts for different transport segments. Further, it is not very common to emphasize variability in human perception and behaviour in current posture prediction models [i.e. 10-12]. Accommodating the needs of the total truck driver population is challenging and some issues are also related to regulatory aspects. In cab over engine trucks, which commonly are used in Europe, the driver space is often limited as a result of the regulation on maximum vehicle length and the total cab length in relation to the load length.

This paper presents truck drivers' own opinions and requirements on current and future driver position layouts, and outlines a combination of an explorative semi-structured interview study and a literature study. The aim was to understand truck drivers' expectations on both current vehicles and future trucks with an expected increased level of automation, and to see how the expectations relate to previous driving posture related research. Method

The result of this paper is based on a combination of an explorative semi-structured interview study and a literature study. The combined approach was chosen in order to determine factors influencing truck drivers' choice of sitting posture and how their requirements on vision relate to posture position. The results from the interviews were compared to results found in scientific literature in order to understand if truck drivers' opinions, requirements and personal preferences match previous research results.

2. Method

The result of this paper is based on a combination of an explorative semi-structured interview study and a literature study. The results from the interviews were compared to results found in scientific literature in order to understand if truck drivers' opinions, requirements and personal preferences match previous research results.

2.1. Interviews

Interviewees

In total, 9 truck drivers (7 males, 2 females) were included in the study. The recruitment was made through a database of test drivers from Volvo Trucks in Gothenburg, Sweden. All interviewees had experience of truck driving, but some of them were not currently working as professional drivers. In the cases where the interviewees were not working as professional drivers, they were occasionally driving trucks within their profession. All interviewees were

accustomed to driving Volvo trucks, and in particular the FH, FM and FMX models.

Personal characteristics of the interviewees were collected through a form that was filled out by each interviewee before the interview. The characteristics are summarised in Table 1.

Table 1. Characteristics of interviewees.

No.	Male / Female	Age	Licence [yrs.]	Professional [Y/N]	Experience [yrs.]	Stature [cm]
1.	F	35	14	Y	13	171
2.	F	39	28	Y	28	175
3.	M	39	20	Y	29	194
4.	M	40	14	Y	14	186
5.	M	56	20	N	10	174
6.	M	60	32	N	3	185
7.	M	46	20	N	0*	183
8.	M	61	25	N	0*	177
9.	M	60	37	N	0**	182

*Occasional driving within profession.

**37 years of driving 15 000-25 000 km/year

Professional refers to if the driver was working as a professional driver at the time of the study.

Experience refers to how many years the driver previously had worked as a professional driver.

Procedure

All interviews were held by one single interviewer (first author). Each interview was recorded with a ZOOM H2N Handy Recorder and written notes were taken continuously during the interviews.

The duration of each interview was approximately 45 minutes and consisted of questions on three main topics:

- The interviewee's choice of sitting posture in relation to different driving environments
- The interviewee's visual behaviour in relation to sitting posture and different driving environments
- The expectations on future truck driving layout environments in relation to increased automation

The intention behind performing semi-structured interviews was to allow an explorative approach where the interviewees were encouraged to fully express themselves on each of the questions. It also allowed the interviewer to ask follow-up questions on answers of significant interest. The interviewees were encouraged to answer all questions in regard to their personal preferences. The interviewer also prompted the participants when needed in order to encourage them to make helpful verbalisations.

The data was analysed through a thematic analysis. While listening to the interviews, comments of significant interest were written down on notes. These notes were sorted into categories and the intention was to develop themes and discover patterns in the responses.

2.2. Literature Study

The literature study was focusing on factors that have been found to determine truck drivers' visual behaviour during drive, and how they choose sitting posture in relation to different driver environment layouts and different driving contexts. The approach was to divide the literature search into two different main areas. The first area regarded factors inside the truck cabin (i.e. seat, adjustability, reachability of controls, overall cockpit layout) and the second area included contextual factors (i.e. driving task, driving environment). The databases *SAE Digital Library* and *Scopus* were the main sources of literature together with previous research made at Chalmers University of Technology [8;9; 13;18; 20].

3. Results

For each of the sub-sections in the result chapter, results are presented in the following order. First, results from the interview study are presented and second, these results are compared to findings from scientific literature.

3.1. The ‘optimal’ sitting posture

The interviewees typically mentioned that an optimal sitting posture is a comfortable posture allowing sufficient visibility. This also related to posture changes and according to the interviewees’ perception, posture changes are usually due to either an objective of enhanced comfort or enhanced visibility. Most of the interviewees shared a common understanding that dynamic sitting could be beneficial. There was, however, none of them who could express a theoretical reason to why it should be positive for the driver.

According to the literature study researchers seem to agree more on what driver environments should offer in terms of ergonomic features than how an ‘optimal’ sitting posture is achieved. A vehicle seat should for instance through its design encourage and invite the driver to choose an ergonomically beneficial posture [13] and a seat that locks the body in one ‘optimal’ sitting posture is not ideal as it hinders dynamic sitting behaviour [14]. A vehicle seat should also offer opportunities for posture change and body movement to avoid muscular fatigue and strained body positions [14; 15]. The medical aspect of postural movement is often emphasized. Postural movement is essential for reasons such as musculoskeletal health, facilitation of nutrition, and relief of muscle fatigue.

There are examples of studies where test subjects are manipulated via seat features to choose pre-defined ‘ideal’ postures [15-18], but there is a lack of consensus among the researchers of what an ‘ideal’ sitting posture is [13; 19].

A truck driver’s choice of sitting posture is according to literature dependent on several different factors. Some are clearly related to the driving environment layout and some distinctively related to the driver’s individual and personal preferences. Fatollahzadeh [11] also mentions how it is possible that no optimal posture can be obtained. No indications have been found on that a driver’s choice of posture should be related to the intent of seeking what is inscientific literature described as an optimal posture. Instead, other factors seem to influence the choice.

In a study on long-haulage driving, a large percentage of posture changes could be linked to events inside the truck (talking on the phone, tune the radio, eating, drinking etc.) or external events caused by the current traffic situation (overtaking, braking, roundabout driving etc.) [8]. Individual variation was also found to be large in terms of how often the drivers were repositioning while driving, something which also has been acknowledged by other research [12]. However, both car and truck drivers tend to have one favourite sitting posture and the exception is minor repositioning for a short while, before drivers return to their favoured position again [8; 13; 20]. Drivers tend to have an adjustment period of about 15 minutes at the beginning of a journey, where the change is more frequent, before they find a comfortable position. After this short period, posture changes are less present. However, postural repositioning increases again after about two hours.

3.2. Factor’s influencing sitting behaviour inside the cab

When asking the interviewees about factors contributing to their perception of comfort inside the truck cab and factors positively affecting their sitting behaviour, the seat and its adjustability were commonly mentioned as the main contributors. Volvo Trucks has provided their drivers with 40 mm extra seat adjustment range in their latest FH-model released in 2012 [21]. The range is thereby extended from 200 mm to 240 mm and this increases the possibilities of freely choosing sitting posture, primarily for taller drivers. However, all interviewees with a stature of 185 cm or more mentioned that they wanted even more space to fully be able to choose their favoured posture. A stature exceeding 185 cm relates to the tallest 5th percentile of the Swedish male adult population [22] and the interview results indicate that the needs of these drivers are not fully accommodated by Volvo’s current design. Some interviewees also mentioned the lowest point of the seat height adjustment as too high for shorter drivers, even though these problems were not self-experienced. Further comments included positive feedback on the possibilities of personalising the seat through its wide range of adjustability features. The steering wheel adjustment was another appreciated feature, and a majority of the interviewees mentioned the benefits of the neck tilt function in the Volvo FH. The function allows further freedom when adjusting the steering wheel, and both taller and shorter interviewees expressed a positive attitude towards it.

When discussing factors having a negative impact on comfort and sitting, four interviewees did not experience

any problems at all. The other five mentioned the seat belt and the longitudinal adjustment range of the seat as the most disadvantageous factors. The comments on the seat belt included the limitations of not having an adjustable seat belt and how discomfort provided by the seat belt sometimes forced the interviewees to choose undesirable postures to avoid further discomfort. However, it was also mentioned that integrating the seat belt into the seat has been a major design improvement.

There are previous studies demonstrating difficulties in freely choosing or changing body postures as a result of the driving environment design [8]. In the previous Volvo FH cabs, clear limitations were found in adjusting the backrest according to the lack of space behind the driver. The seat belt has also been mentioned in previous studies as a factor influencing the possibility of freely choosing body posture, and major posture changes are difficult to accomplish when using a seat belt [20]. This is particularly interesting since truck drivers have been found to change sitting posture more frequently than car drivers. The main reasons are that truck drivers use their seat belts less frequently, use the cruise control more often, and differences in the overall interior design. The main reason for drivers to not use the seat belt is the relative decrease in driving comfort [23].

Discomfort is not only due to user's physical experiences over time, but also to psychological matters. A seat that is perceived as non-comfortable may actually appeal to the user because of its aesthetical appearance [14]. In previous studies on aircrew performance, seat design is mentioned to be one of the primary contributors to comfort [24]. This has also been shown for child restraint systems in cars [25;26].

3.3. Contextual factors influencing sitting behaviour

When discussing contextual factors influencing sitting behaviour, inner city driving was commonly mentioned during the interviews. All interviewees except one agreed that other postures were chosen when driving in inner city environments compared to highway driving. Inner city driving was described as more complex, with more unexpected events taking place around the truck (caused by pedestrians, cyclists and other road users). The interviewees were conscious of their choice to adapt the sitting posture to the current driving environment. All of them explained how they leaned forward during driving situations that they perceived as requiring more control, where they needed to observe and be aware of what happened close to their vehicle. Examples were when driving in urban environments but also on highways with a lot of traffic. Most of the interviewees mentioned that there is a difference between a heavily trafficked highroad and a road in a more urban setting. The anxiety of unexpected events caused by the surrounding vehicles was significantly more present when discussing urban settings compared to highway driving.

The interview results also indicated that there is a difference in how drivers position their bodies during urban driving and highway driving. The interviewees experienced greater opportunities to relax during long haul operations compared to inner city driving. The experience of relaxing opportunities seemed to increase with the duration of the drive. It was common that the interviewees removed their shoes and adjusted the backrest further back during longer highway drives. Several interviewees also mentioned how they chose body postures that are not intended in the cab during drive. Especially taller drivers (≥ 185 cm) explained how they used the interior to accomplish peculiar postures. This was expressed in terms of placing the left foot on the interior or both feet on the dashboard, on the right side of the steering wheel.

There are studies showing that comfort often overrules theoretically ergonomic beneficial postures, and that this also influences how drivers choose to position their body [9]. According to literature, contextual factors have an impact on postural behaviour when driving trucks, and as many as half of the changes in sitting posture may be caused by the driving context [8]. The impact of urban traffic as a contextual factor is discussed in a study on taxi-drivers [9]. In inner city driving, it was observed that the taxi drivers needed to be more active and keep better watch over the close environment, which meant a more upright sitting posture with the head slightly tilted forward. The sitting postures became more hunched and the drivers did not use the full functionality of the backrest. This is consistent with the answers given by the interviewees regarding inner city driving.

3.4. The relation between sitting posture and visibility

When the interviewees explained their opinions on what is the most important: the field of vision and comfort, all interviewees agreed that the importance of sitting comfort is higher when driving on highways, whereas visibility

was considered more important during inner city driving.

When discussing the relation between sitting posture and visibility, a majority of the interviewees had the opinion that the relation was very limited or non-existing when driving on highways. The visibility provided from their favoured position was perceived as sufficient, and no interviewee expressed that they changed their sitting posture during highway driving to get better visibility. The opinions were very different when discussing inner city driving. The exact phrasing varied between the interviewees, but there was a common understanding of that inner city driving definitely affected postural behaviour. All interviewees described how they adapted a more 'active' sitting posture in urban environments. This was expressed as a more forward leaning posture, where the upper and often also lower back leaved the backrest. Depending on the complexity of the driving task, sideways motions were also described. The comments were that increasing complexity in the driving task also meant an increase in the visibility's effect on the sitting posture. When experiencing increased complexity in the driving task, all interviewees expressed a wish to find a better overview over the situation, resulting in more postural movement.

Another factor influencing the relation between sitting posture and visibility mentioned during the interviews was the rear view mirrors. In their latest FH-models, Volvo has provided some new design features for increased visibility. The windshield is more upright and the rear view mirrors have also been made smaller to increase the forward direct visibility[21]. The interviewees appreciated these features, and all of them mentioned the positive effect of increased direct visibility. Several interviewees mentioned that the decreased size of the mirrors meant that less undesired postural movement was needed to see objects hidden by the mirrors. The rear view mirrors and the wide-angle mirrors are also separated on the latest FH-models. This creates a gap between the mirrors, which allows the driver to spot other road users and that previously have been completely hidden behind the mirrors. The interviewees also described this feature as beneficial for the driver.

Vision is according to several previous studies the most important sense modality when manoeuvring vehicles [2; 9; 13; 27]. Literature mentions how a good field of vision is almost always prioritized over seat comfort. Further, the visual information given by mirrors is more important in trucks than in passenger cars [27].

3.5. Expectations on future truck driving environment layouts

None of the nine interviewees were familiar with the term 'autonomous vehicles'. When being further informed, a few of them could recall that there is current development on autonomous driving. Whilst 'autonomous vehicles' is a hot topic in the research society, the knowledge of the interviewees was very limited on this subject. A majority of the interviewees were also sceptical towards the thought of facing self-driving trucks in a near future.

When discussing possible future development, the interviewees found it difficult to predict how increased automation possibly would affect postural behaviour. Most interviewees were questioning the possibilities of a change in the working task due to increased automation. A few of them could imagine that drivers of vehicles with increased automation could perform some administrative tasks while operating the vehicle, but it was far more common to receive comments on increased possibilities for comfortable driving positions, resting or entertainment (i.e. using the internet) than expectations on a change in the working task. The importance of trusting the system and controlling the system performance was commonly the reason to why there was scepticism towards performing working tasks not related to driving or operating the driving system. When prompted to imagine that the driver would act more like an operator overseeing a technical system rather than a driver, most interviewees mentioned the importance of being able to perform such working task in a comfortable position as more important than accommodating further possibilities of administrative tasks through the driver position layout.

When discussing higher levels of automation, several interviewees mentioned possible problems related to boredom. This also led to further discussions on what is needed in truck driving environments to accommodate needs related to increased boredom. Several interviewees highlighted the importance of freedom in choosing posture and the ability to frequently change body position. However, no interviewee specifically mentioned how the postural behaviour could change as a result of increased automation.

4. Discussion

The purpose of this paper was to explore truck drivers' expectations on current and future truck driving layouts and compare that to related research results. The explorative approach has provided increased understanding of truck

drivers' opinions on both current and future driver environment layouts. However, the study was limited to nine Swedish participants accustomed to drive Volvo trucks and it might be difficult to apply the results to other truck driver populations. The interview results have also been highly focusing on features in Volvo's current FH, FM and FMX models. This was due to what trucks the interviewees were used to driving. Therefore, models by other manufacturers have not been considered. By conducting interviews with drivers accustomed to trucks from other manufacturers, the results could have been different.

The results presented in this paper acknowledges the importance of emphasizing the freedom of choice rather than seeking ways of placing drivers in pre-defined 'optimal' sitting postures. Features in the driver environment promoting individual adjustments, possibilities of greater individual variation and less undesired postural movement were in general largely appreciated. On the contrary, features that hinder the possibilities of freely choosing a preferred posture were considered negative. The wishes of achieving a comfortable sitting posture are even prioritized higher than safety in some cases (i.e. placing feet on dashboard or deselecting the seat belt). By encouraging development on truck driving environments that emphasizes the possibilities of freely choosing body posture, it could be possible to accommodate wishes from the drivers without decreasing safety.

During long-haul operations, most of the interviewees preferred a comfortable sitting posture over visibility while the relation was the inverse for inner city driving. These findings are not consistent with information found in literature on both truck and car driving, where it is stated that visibility is almost always prioritised over comfort [2;9; 13; 27]. However, it is likely to assume that the interviewees in the study presented in this paper considered current visibility in trucks sufficient even when choosing a more comfortable posture during highway driving. The importance of visibility is, however, increasing with an increased complexity of the driving task. Answers from the interviewees mentioned that there are some notable differences between how much the driving context affects postural behaviour between inner city and highway driving. This implies that there should be differences between driver environment layouts for different transport segments, and that visibility aspects should be further emphasized in layouts for cabs primarily used in inner city traffic. By accommodating the needs of the drivers in each specific transport task, it should be possible to increase both comfort and safety. However, further studies are needed to more specifically determine which aspects regarding visibility should be further emphasized.

When discussing the future involving higher levels of automation, the interviewees continuously mentioned the possibilities of increased relaxation behind the steering wheel. This could also be interpreted as expressing a desire for increased freedom. In this case, not only regarding a good ergonomic driving environment but also for the complete driving situation. But what happens in the future if drivers choose postures that could increase the risks of work-related injuries or decrease safety? With a limited knowledge in both ergonomics and crash safety, such behaviour is quite probable. Too much freedom could thereby create problems rather than further benefit for the drivers' well being. This shows that there is a trade-off between accommodating the subjective requirements of the drivers and providing necessary features for encouraging ergonomically beneficial postures.

The results also indicated that there are differences in the developers' intentions regarding a good ergonomic working environment and how drivers actually use the driver environment. In order to develop future driver environment layouts accommodating the drivers' requirements, their opinions must be considered in the product development process. However, a more common understanding could also be reached by educating the drivers in how to use the driver environment properly or to increase acceptance of design solutions in other ways. It is important to consider comfort, safety and effectiveness in the work environment. Experts in the respective fields should lead such development in order to sufficiently accommodate it, but with user involvement.

5. Conclusions

- The explorative approach has provided increased understanding of truck drivers' opinions on both current and future driver environment layouts, but is limited to only include nine Swedish participants accustomed to driving Volvo trucks.
- Individual variability has a large impact on the choice of sitting posture when driving trucks, and future development of driver environment layouts should allow drivers to freely choose body posture.

- There is a difference on postural behaviour when driving in different contexts. In inner city driving, drivers adapt a more ‘active’ sitting posture and driving on highways generally generates a more relaxed posture. Increasingly complex environments put higher demands on visibility than on comfort, and future development should acknowledge these differences.
- In future driving environment layouts, including increased automation, drivers expect further opportunities to find comfortable driving postures and to relax rather than changes in their working task.

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