QUANTITATIVE CHARACTERISATION FOR NON-DRIVING-RELATED ACTIVITIES IN AUTOMATED VEHICLES

Fitzen, Florian (1); Reimann, Jan (1); Amereller, Maximilian (1); Paetzold, Kristin (2)

1: BMW AG; 2: Bundeswehr University Munich

ABSTRACT

The technological progress to automated driving not only influences the motion of the vehicle itself but also enables passengers to productively shape their driving time in a new way as they are not occupied with driving tasks anymore. Therefore, non-driving-related activities such as sleeping, working on a notebook or watching movies, become relevant user scenarios for functionally designing the automotive interior. For this purpose, a non-driving-related activity can be described by functions, which support the users in performing their intentional tasks, and functions carriers, which fulfil one or several functions. Basing on previous research findings, a quantitative survey is conducted in order to identify relevant and prioritised functions and function carriers. Five non-driving-related activities are taken into account: 'Making a call', 'sleeping', 'watching a movie', 'talking to passengers' and 'working on a notebook'. Results show a significant difference between general relevancy and specific prioritisation of functions and function carriers. In this contribution, the setup of the study is described, the outcome exemplified and further research steps are deduced.

Keywords: User centred design, Requirements, Innovation, Non-driving-related activities, Automated Driving

Contact:
Fitzen, Florian
BMW AG
Interior
Germany
florian.fitzen@bmw.de

Cite this article: Fitzen, F., Reimann, J., Amereller, M., Paetzold, K. (2019) 'Quantitative Characterisation for Non-Driving-Related Activities in Automated Vehicles', in *Proceedings of the 22nd International Conference on Engineering Design (ICED19),* Delft, The Netherlands, 5-8 August 2019. DOI:10.1017/dsi.2019.296

1 INTRODUCTION

Until 2035, traffic researchers forecast a share of autonomous vehicles between 17% and 42% of the total vehicle fleet in Germany. For the US market, they estimate a proportion of 11% in worst case and 32% in best case scenario (Trommer *et al.*, 2016). According to a forecast by the leading market research institute Navigant Research, nearly 100 million self-driving vehicles will be sold by 2035 (Wirtschaftswoche, 2013). This also means, referring to Johanning and Mildner (2015, p. 75), that only a few conventional vehicles will be sold then. Until now, only a few researchers were concerned with the impact of longer time spans in automated vehicles and what that means for users and developers. At this point, it is only known that occupants will be very likely performing another activity during an automated drive, but not of which kind this activity will be (Feldhuetter *et al.*, 2018, p. 15ff.). Through the technological progress, a lot of new user groups will be worth considering for the automotive industry which then makes the product more attractive due to various use cases during the drive itself. A study by Trommer *et al.* (2016) stated, that this will result in three to nine percent more kilometres driven. The higher complexity of traffic patterns will lead to a higher number of traffic jams and parking searches, which will strengthen the users' needs for a vehicle that is able to adapt to different situations. This requires a flexible and individual interior concept which enables the occupants to productively shape their driving time and reach their destination in a relaxed state of mind (Tomforde, 2007, p. 208ff.). Fraunhofer IAO and Horváth & Partners (2016) as well as others already dealt with researching on users' needs during an automated drive, which lead to the field of non-driving-related activities. This term includes all tasks that are not related to driving, such as operating comfort or infotainment systems. And also activities that become possible with the automated driving belong to it (Pfleging and Schmidt, 2015, p. 3). These aspects make it essential to differentiate the interior design between different non-driving-related activities. While 'working' in an automated vehicle may require a table, various shelves and input and display options, a comfortable seating or lying position in combination with a dark environment may be more important for the non-driving-related activity 'sleeping'. This might also be different for 'virtual sightseeing', 'watching a movie' or 'working out' in an automated vehicle (Fitzen *et al.*, 2018, p. 2). The need for 'bigger, smarter and more functional storage' is also shared by David Muyres, executive director for advanced products at Yanfeng Automotive Interiors (Berman, 2016, p. 2). Therefore, it can be concluded in general that a need for detailed data regarding the realisation of non-driving-related activities in automated vehicles on the development side of the vehicle exists, which this contribution will be concerned with.

2 RESEARCH GAP AND OBJECTIVES

Previous research in this field was rather concerned on identifying relevant non-driving-related activities than describing them in detail. Petermann-Stock *et al.* (2013) classified non-driving-related activities regarding the demand level and the user demand which is addressed. They split into cognitive, acoustic, visual and motor demands and categorised all activities into these four. While 'making a call' includes a cognitive and acoustic demand, 'working on a notebook' additionally requires visual and motor interaction. This scheme was also picked up by Feldhuetter *et al.* (2018). Fitzen *et al.* (2018) then used this approach in order to categorise functions and function carriers for non-driving-related activities. In this context, functions are known as what the driver or user intends and to what extent the technical system supports him (Braess and Seiffert, 2003, p. 667). The function carrier then realises the function in technical solutions (Vietor and Stechert, 2013, p. 865). Function carriers can either be components or assemblies which fulfil a function (Ehrlenspiel, 2009, p. 44; Feldhusen *et al.*, 2013, p. 311).

Table 1: Relevant functions for the non-driving-related activity 'working on a notebook' (Fitzen et al., 2018)

Ensuring a quiet environment	Transmitting few jerky movements of the vehicle	Ensuring a comfortable temperature
Enabling darkening	Ensuring access to the internet	Generating a pleasant odour
Providing massage functions	Offering an interior that is inspired by nature	Enabling comfortable and variable seating position
Enabling arm support	Enabling leg rest	…

https://doi.org/10.1017/dsi.2019.296 Published online by Cambridge University Press

These function carriers as well as user functions were previously collected and merged through automotive-related and non-automotive literature, whereas all possible information was collected. For the non-driving-related activity 'working on a notebook' the identified functions are shown in Table 1. The same procedure was performed for function carriers. The list of function carriers for 'working on a notebook' is shown in Table 2 in extracts.

Table 2: Relevant function carriers for the non-driving-related activity 'working on a notebook' (Fitzen et al., 2018)

Notebook	Keyboard	Smartphone
Table	Headphones	Armrest
Houseplant	Tablet	Earmuffs
Pillow	Mouse	…

The displayed data not only exists for the non-driving-related activity 'working on a notebook', but also for four other activities: 'Making a call', 'sleeping', 'watching a movie' and 'talking to passengers'. What is not available so far is quantitative data regarding these functions and functions carriers which was identified as the addressed research gap. In order to functionally describe non-driving-related activities for vehicles an approach to acquire and apply more detailed data is needed. In this regard the following research questions can be derived:

1. How do we establish a quantitative basis for the characterisation of non-driving-related activities?
2. What are the priorities for functions and function carriers for potential vehicle users during non-driving-related activities?

The aim of this contribution therefore is to collect and present quantitative data on relevant functions and function carriers for non-driving-related activities. This should serve as a basis for the functional design of the interior for automated vehicles.

3 SPECIFICATION OF FUNCTIONS AND FUNCTION CARRIERS

For the specification of functions and function carriers different methods were taken into account. Due to the need for quantitative data and standardisation a quantitative survey was chosen as the most appropriate method (Döring and Bortz, 2016, p. 405).

3.1 Study method and setup

The mentioned functions and function carriers gathered through literature research from Fitzen *et al.* (2018) were used as a basis for setting up the survey. As the respondents should not be occupied for more than ten minutes when answering the survey, the five investigated non-driving-related activities were split into two different surveys. The first survey contained questions on 'sleeping', 'watching a movie' and 'talking to passengers', whereas the second one included the exact same questions on 'working on a notebook' and 'making a call'. As only the results within every activity should be part of the final evaluation and no interconnection between the two samples was intended, this was chosen to be a suitable approach. The allocation of respondents to survey 1 or 2 was made through a tool-based randomisation.

For the first survey on 'sleeping', 'watching a movie' and 'talking to passengers', $n_1 = 31$ experts from the automotive industry were asked. They all came from different departments such as development, market research, finance, organisational management and production. The second survey on 'working on a notebook' and 'making a call' collected answers of $n_2 = 32$ experts from similar departments. The survey started with a short introduction into the topic using the example of a situation the user should empathise.

'You are driving in an autonomous vehicle on public roads. You do not have to take on any driving tasks. The vehicle is based on today's models, but you can imagine the interior as flexible and individually designable. In the following survey, you will be asked questions about various other activities - termed non-driving-related activities - that you can perform instead of driving tasks.'

For all non-driving-related activities, the survey then asked for selecting all relevant functions from a list such as pictured in Table 1. From all selected ones, the respondents were told to filter their top five functions that are essential for the respective non-driving-related activity. This procedure was

https://doi.org/10.1017/dsi.2019.296 Published online by Cambridge University Press

performed for function carriers as well before proceeding to the next activity. The order of functions and function carriers was randomised for every respondent.

3.2 Results

First of all, a statement on the general relevance of functions and function carriers was found to be interesting. From the selection of relevant functions a list of the ten most selected ones could be derived. Therefore, only the yes or no-selection was taken into account by counting the respondents that selected a function. The most relevant functions for every non-driving-related activity are shown in the following Table 3.

Table 3: Ten most relevant functions for every non-driving-related activity

	Working on a notebook	Making a call	Sleeping	Watching a movie	Talking to passengers
Allowing pleasant head inclination and good view of the screen				x	
Amplifying network reception		x			
Enabling arm support	x			x	x
Enabling comfortable and variable seating position	x	x	x	x	x
Enabling darkening			x		
Enabling eye contact					x
Enabling good audio and video quality		x		x	
Enabling leg rest	x	x	x	x	
Enabling other activities					x
Enabling watching a movie with several people				x	
Ensuring a comfortable temperature	x	x	x	x	x
Ensuring a quiet environment	x	x	x	x	x
Ensuring access to the internet	x			x	
Generating a pleasant odour	x		x		
Offering an interior that is inspired by nature	x				
Offering double bed			x		
Offering possibilities for research		x			
Protecting privacy		x	x		x
Providing adjustable and different coloured illumination	x				x
Providing background music					x
Providing contactless telephoning		x			
Providing intelligent alarm function			x		
Transmitting few jerky movements of the vehicle	x	x	x	x	x

It appears that some of the functions are relevant for every non-driving-related activity in the eyes of the respondents. ‘Enabling a comfortable and variable seating position’ apparently is required for every activity, which is explainable by the need of individualisation and flexibility for the occupants. The same applies to ‘ensuring a comfortable temperature’, ‘ensuring a quiet environment’ and ‘transmitting few jerky movements of the vehicle’. These are functions that can be directly related to the comfort pyramid from Bubb (1995), whereas vibrations & light, noise and climate are three out of four factors that significantly influence the environmental comfort. The mentioned four functions therefore, as they are named for every non-driving-related activity, seem to be very basic functions that the respondents apparently expect in a vehicle during an automated drive. With restrictions this can be also stated for ‘enabling leg rest’, which is relevant in all activities except for ‘talking to passengers’. On the other hand, some of the functions are very specific and therefore only relevant for one activity. This applies to twelve out of 23 functions that were identified as the most relevant through the survey. For ‘sleeping’, this is applicable for the functions ‘enabling darkening’, ‘offering double bed’ and ‘providing intelligent alarm function’. These functions make less sense for the other

https://doi.org/10.1017/dsi.2019.296 Published online by Cambridge University Press

non-driving-related activities, for what reason this seems as a valid result. ‘Watching a movie’ and ‘working on a notebook’ explicitly necessitate leg rest and arm support, which in combination with ‘enabling a comfortable and variable seating position’ complete the picture of a holistic comfort experience for the two activities. By analogy with this procedure this was also used for function carriers, whereas their relevancy per each activity is shown in Figure 1.

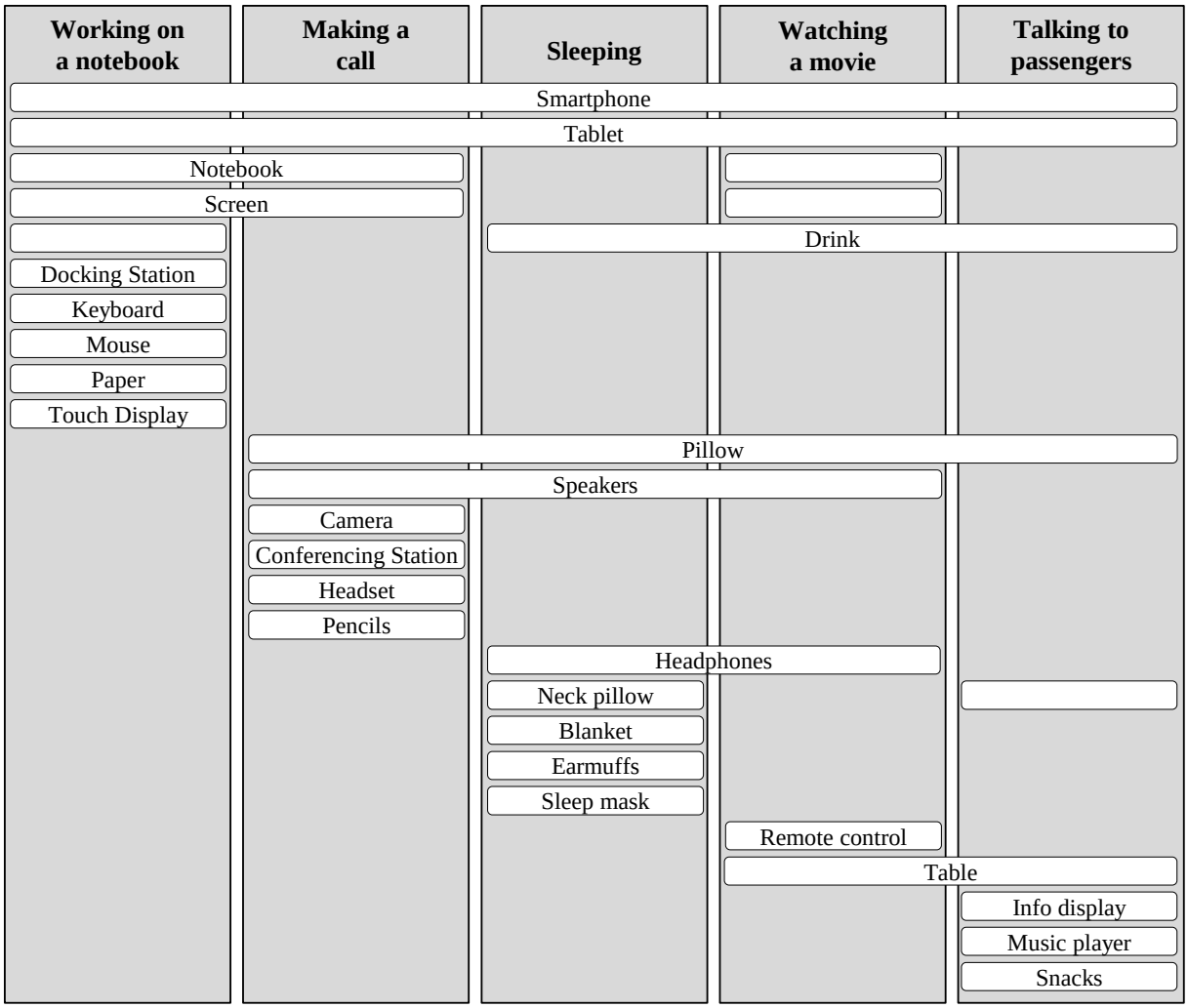

Figure 1: Ten most relevant function carriers for every non-driving-related activity

It stands out that there are two function carriers that occur as mostly relevant in all non-driving-related activities, which are ‘smartphone’ and ‘tablet’. At first this seems surprising for the activity ‘sleeping’, but in general few function carriers were selected for this activity, which might be an explanation. Also, the respondents could have imagined ‘smartphone’ and ‘tablet’ as instruments to access music in order to create a more pleasant surrounding while sleeping. The same fact applies to the function carrier ‘drink’, which is also relevant for all other activities except for ‘making a call’. According to the respondents a ‘pillow’ is needed for all activities except for ‘working on a notebook’. Overall, 15 out of 26 function carriers which occur in the ten most relevant of each activity only are mentioned in one activity. For example, ‘working on a notebook’ is required to have a lot of different function carriers according to the respondents. Five out of ten of them are only relevant for this activity, for instance a docking station, a keyboard and a mouse. On the other hand, ‘sleeping’ makes a blanket, earmuffs and sleep mask necessary, which are all exclusive for this activity. In general not all vehicle integrated components or assemblies are named in this survey. One example can be given by the seat, which would probably be relevant for every activity as well. As the purpose of this survey mainly was to identify differences between the characterisation of non-driving-related activities, this seems like a valid result.

Based on this data set it was deemed necessary not only to have a rating of functions and function carriers by the number of selection, but also by the rank the item was given by the respondents. Of

https://doi.org/10.1017/dsi.2019.296 Published online by Cambridge University Press

course, this does not enable concluding distances between items, but at least gives insight on the priorities the respondents had in the survey. The comparison between the average rank and the number of selections is shown in Figure 2 for functions within ‘working on a notebook’.

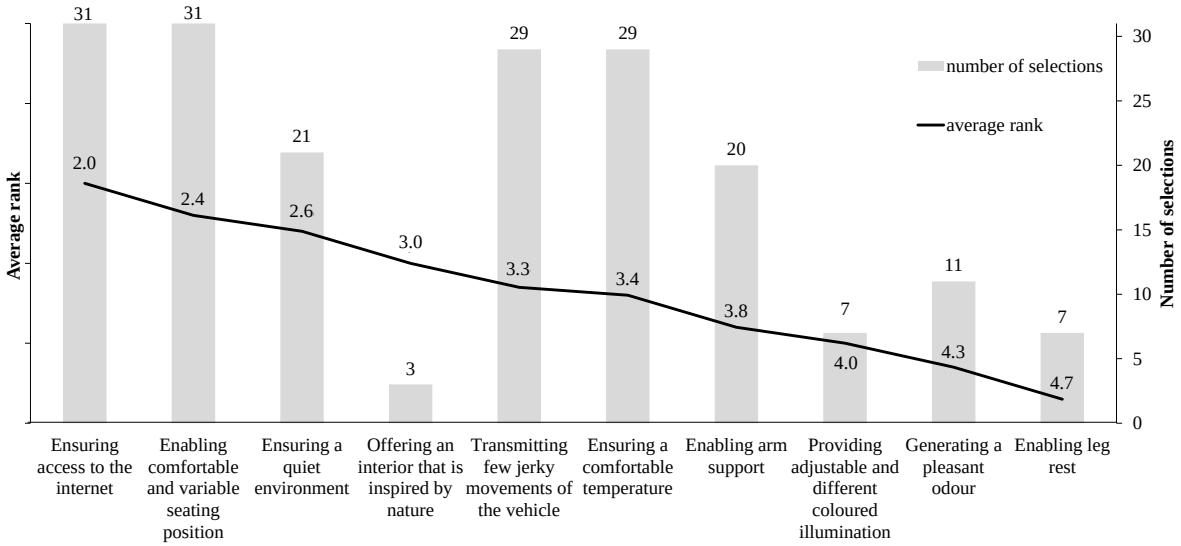

Figure 2: Average rank and number of selections for each function in ‘working on a notebook’

The functions are sorted by rank, whereas the best ranked item ‘ensuring access to the internet’ is shown on the left. 31 of 32 respondents selected this function as relevant for ‘working on a notebook’ at all. The average rank for this item derived from the task of naming their top five functions in order is 2.0. Having a closer look it also appears that ‘offering an interior that is inspired by nature’ was generally only selected by three respondents, which is a low number compared to the other functions. The three respondents rather ranked this item important for this activity resulting in an average rank of 3.0, which makes it the fourth most important function for ‘working on a notebook’. On the other hand, ‘transmitting few jerky movements of the vehicle’ was generally chosen by a lot of respondents. 29 out of 31 possible interviewees think this function is needed for ‘working on a notebook’. But when it came to prioritising the functions, it was only ranked with an average of 3.3. ‘Ensuring a quiet environment’ as an example is chosen by fewer people but prioritised higher, which makes it third most important function. The same approach can be used for the function carriers as well. All in all it appears that four different types of functions can be determined. The first possibility, that a function is named by a lot of respondents and ranked high, as well as the second, that a function is not chosen a lot and is also not ranked high, are the rather normal possibilities. The next option can be found with the fact that some functions and function carriers are selected for belonging to an activity, but they are not ranked very high. This can be interpreted the way that it is not characterising for this non-driving-related activity. On the other hand, some functions and function carriers are only chosen by a few respondents, but they define it to be characterising for an activity. Hereby the relevance of the items should be reconsidered due to the low number of selections. When functionally designing the interior of automated vehicles this can be seen as a decision basis for prioritising functions and function carriers in the interior.

Another evaluation of the data set was performed with a principle component analysis using the guidelines of Backhaus (2011) and the software SPSS. The goal of this analysis is to identify further relationships within functions or function carriers. As an example, the analysis of functions for ‘working on a notebook’ is shown in Figure 3.

https://doi.org/10.1017/dsi.2019.296 Published online by Cambridge University Press

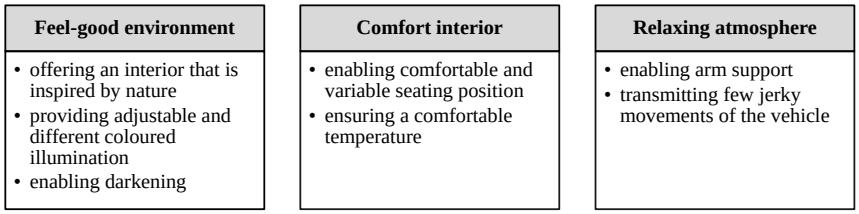

Figure 3: Functional clusters identified through principal component analysis for the non-driving-related activity 'working on a notebook'

All in all, three components could be identified. Within these components, respondents preferentially selected the functions together. 'Offering an interior that is inspired by nature', 'providing adjustable and different coloured illumination' and 'enabling darkening' were summarised under 'feel-good environment'. The component 'comfort interior' is described by the functions 'enabling comfortable and variable seating position' and 'ensuring a comfortable temperature'. The third component was named 'relaxing atmosphere' and contains of 'enabling arm support' and 'transmitting few jerky movements of the vehicle'. For the developers it is consequently recommendable to realise rather more functions within one component than one function of every component in order to create a harmonious holistic experience.

4 CONCLUSION AND DISCUSSION

In this contribution a survey on relevancy of functions and function carriers for non-driving-related activities during automated driving was elucidated. On the basis of existing research on functions and function carriers the suitable method for data collection was considered to be a quantitative survey. The survey was conducted online with 31 respectively 32 respondents for five different non-driving-related activities. The respondents came from within the automotive industry, but covered all kinds of departments. The results generally show, that functions and function carriers are seen quite diverse. When it comes to determining relevant items, there are ones that are perceived basic and ones that are characterising for activities. Also, preferences on selecting functions and function carriers together could be stated here. The results allow the developers to understand the future occupants' needs during automated driving better and enables them to set priorities when functionally designing the interior. The results of the principle component analysis also make the clustering of functions and function carriers possible and accentuate the need for individualisation in the vehicle. This lays the basis for a differentiation of target group, e.g. when deciding which activity and how it will be enabled in a certain vehicle class or type. Thinking ahead this also might let the car manufacturers think about re-structuring offer packages of features or services for automated vehicles.

Basing on this contribution an expansion of the data base seems useful for further research. On the one hand, more than the considered five non-driving-related activities should be taken into account. Also, this survey was performed with experts from the automotive industry. Although the participants came from different departments and were not necessarily part of the interior development, an execution of the survey outside the automotive industry can be a valid next step in order to compare the results of automotive affine respondents to completely unbiased people. When having a look at function carriers, the consideration of vehicle-integrated items such as seat, cockpit, steering wheel or coverings seem to be relevant function carriers which were - due to the consciously automotive neutral literature research - not part of this study. In the end, all the gathered information could be put into building up ideal situations for non-driving-related activities. These mock-ups could be used for comparison as well as validating the raised data in a real environment.

All in all, the transition to automated driving will probably have a significant impact on the automotive interior. The investigated non-driving-related activities might also change over time, as the passengers will get used to the situation and therefore feel more comfortable in an automated vehicle. When higher automation levels up to autonomous driving will be available, the whole vehicle layout can also be designed in a new way. The passengers might be able to have permanent eye contact in a conferencing layout, which easily can be changed to a relaxing situation including a generous laying surface for the next trip. This will be possible as the necessity of a takeover by the passengers in a critical situation will not be existent any more. Consequently the functionality and therefore the variety of functions and function carriers might be broader than anticipated in this contribution. This

https://doi.org/10.1017/dsi.2019.296 Published online by Cambridge University Press

can include e.g. type and positioning of screens, user interaction concept as well as variety and attributes of storages. Also, challenges such as motion sickness, which describes an incongruity between the visual perception and the vestibular system's sense of bodily movement, as well as their causes and possible prevention will have to be investigated more detailed in order to enable the optimal traveling situation in an automated vehicle. Due to these influencing factors it can be useful to perform this survey again in a few years, as the volatile acceptance of automated driving definitely has an essential impact on the use of travel time.

REFERENCES

Backhaus, K. (2011), *Multivariate Analysemethoden: Eine anwendungsorientierte Einführung, Springer-Lehrbuch*, 13th rev. ed., Springer, Berlin. http://doi.org/10.1007/978-3-642-16491-0

Berman, B. (2016), "With Self-Driving Cars, It's the Interior That Will Matter. Sit back, relax, and enjoy the ride - literally", available at: http://www.roadandtrack.com/new-cars/future-cars/a30235/with-self-driving-cars-its-the-interior-that-matters/ (accessed 16 January 2017).

Braess, H.-H. and Seiffert, U. (Eds.) (2003), *Vieweg Handbuch Kraftfahrzeugtechnik*, 3rd ed., Vieweg+Teubner, Wiesbaden. http://doi.org/10.1007/978-3-663-11757-5

Bubb, H. (1995), *Ergonomie in Mensch-Maschine-Systemen - Lehrgangsunterlagen "Komfort und Ergonomie im Kraftfahrzeug"*, Haus der Technik, Essen.

Döring, N. and Bortz, J. (2016), "Datenerhebung", in Döring, N. and Bortz, J. (Eds.), *Forschungsmethoden und Evaluation*, 5th ed., Springer, Berlin Heidelberg, pp. 321–578. http://doi.org/10.1007/978-3-642-41089-5

Ehrlenspiel, K. (2009), *Integrierte Produktentwicklung: Denkabläufe, Methodeneinsatz, Zusammenarbeit*, 4. überarb., Hanser, München, Wien. http://doi.org/10.3139/9783446421578

Feldhuetter, A., Hecht, T. and Bengler, K. (2018), *Fahrerspezifische Aspekte beim hochautomatisierten Fahren*.

Feldhusen, J., Grote, K.-H., Nagarajah, A., Pahl, G., Beitz, W. and Wartzack, S. (2013), "Vorgehen bei einzelnen Schritten des Produktentstehungsprozesses", in Feldhusen, J. and Grote, K.-H. (Eds.), *Pahl/Beitz Konstruktionslehre: Methoden und Anwendung erfolgreicher Produktentwicklung*, 8th rev. ed., Springer Vieweg, Berlin Heidelberg, pp. 291–410. http://doi.org/10.1007/978-3-642-29569-0_6

Fitzen, F., Seebach, N., Amereller, M. and Paetzold, K. (2018), "Nutzerorientierte Charakterisierung fahrfremder Tätigkeiten in automatisierten Fahrzeugen", in Krause, D., Paetzold, K. and Wartzack, S. (Eds.), *Design for X: Beiträge zum 29. DfX-Symposium, Tutzing*, 25.-26.09.2018, TuTech, Hamburg, pp. 263–270.

Fraunhofer IAO and Horváth and Partners (2016), *The Value of Time: Nutzerbezogene Service-Potenziale durch autonomes Fahren*, Stuttgart.

Johanning, V. and Mildner, R. (2015), *Car IT kompakt: Das Auto der Zukunft - Vernetzt und autonom fahren*, Springer Vieweg, Wiesbaden. http://doi.org/10.1007/978-3-658-09968-8

Petermann-Stock, I., Hackenberg, L., Muhr, T. and Mergl, C. (2013), *Wie lange braucht der Fahrer?: Eine Analyse zu Übernahmezeiten aus verschiedenen Nebentätigkeiten während einer hochautomatisierten Staufahrt*, München.

Pfleging, B. and Schmidt, A. (Eds.) (2015), "(Non-) Driving-Related Activities in the Car: Defining Driver Activities for Manual and Automated Driving", *Workshop on Experiencing Autonomous Vehicles: Crossing the Boundaries between a Drive and a Ride*, Stuttgart.

Tomforde, J. (2007), "Entwicklung und Design von Freizeitmobilen", in Braess, H.-H. and Seiffert, U. (Eds.), *Automobildesign und Technik: Formgebung, Funktionalität, Technik*, Friedr. Vieweg and Sohn Verlag, GWV Fachverlage GmbH Wiesbaden, Wiesbaden, pp. 202–216. http://doi.org/10.1007/978-3-8348-9411-3_13

Trommer, S., Kolarova, V., Fraedrich, E., Kröger, L., Kickhöfer, B., Kuhnimhof, T., Lenz, B. and Phleps, P. (2016), *Autonomous Driving: The Impact of Vehicle Automation on Mobility Behaviour*, Berlin.

Vietor, T. and Stechert, C. (2013), "Produktarten zur Rationalisierung des Entwicklungs- und Konstruktionsprozesses", in Feldhusen, J. and Grote, K.-H. (Eds.), *Pahl/Beitz Konstruktionslehre: Methoden und Anwendung erfolgreicher Produktentwicklung*, 8th rev. ed., Springer Vieweg, Berlin Heidelberg, pp. 816–871. http://doi.org/10.1007/978-3-642-29569-0_17

Wirtschaftswoche (2013), "2035 werden 100 Millionen selbstfahrende Autos verkauft", available at: https://www.wiwo.de/technologie/green/studie-2035-werden-100-millionen-selbstfahrende-autos-verkauft/13546972.html (accessed 18 October 2018).

https://doi.org/10.1017/dsi.2019.296 Published online by Cambridge University Press