Common Interaction Schemes for In-Vehicle User-Interfaces

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Abstract. In this paper different interaction schemes which are currently implemented by major automotive manufacturers have been identified and analyzed. Complete overviews on all in-vehicle user-interface concepts are rarely spread. This paper gives a deeper insight in interaction schemes and user-interface concepts which are implemented in current cars. Additionally an expert review with 7 experts was performed to get a first impression which user-interface interaction schemes work well in the in-vehicle context. In order to get an impression of the suitability of the interaction schemes for the development of usable in-vehicle user-interfaces we performed different tests. The results are reported in text and tables.

Keywords: User Interface Design, In-vehicle information systems, IVIS.

1 Introduction

The variety of driver information systems (IVIS) continuously increases. Integration of IVIS into a consistent and integrated human centered interaction concept gets more and more important. We have identified and analyzed different human computer interaction interaction schemes which are currently implemented by major automotive manufacturers. The identification of these HCI interaction schemes and the determination of their suitability for the use in cars is the basis for future design and development of intuitive and easily learnable user-interfaces in cars. The identification of interaction schemes and the evaluation of their suitability for the use in cars were performed in a two-stage expert review: Whereas in the first step the general usability was tested (with SUS / SEA), in the second step the usability was tested more specifically (with HMI).

This paper starts with an overview on related work in the field of in-vehicle user-interface concepts. Afterwards it gives an overview on different interaction schemes which are implemented in current automobiles. Finally the evaluation and the evaluation results are presented.

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2 Related Work

Ablassmeier et al. proposed new search techniques for in-car interfaces [1]. Their proposed search agent has a high potential to increase the concentration on the primary driving task.

Burnett et al. focus on the usability of car navigation systems and give a comprehensive overview on the issues concerning human-machine interfaces [2]. Research on in-vehicle information systems quite often is limited to the presentation of navigation information and warnings [5]. Burnett et al. identified a rapid growth of interest in the development and utilization of tactile interfaces in cars [3]. In their opinion the human skin surface offers an important means for presenting information to the users, even if their other senses may already be overloaded. Finally they summarized the arguments for and against allowing drivers to enter a destination with a vehicle system while driving. In their opinion the inhibition of this functionality whilst being on-the-move is not an ideal solution. Consequently the research in user interfaces and human factors has to investigate the potential of novel in-car user-interfaces [4].

Another field of in-vehicle human computer interaction research are considerations of driver distraction. The risk caused by usage of mobile devices is commonly taken into account [6]. Although this study describes different types of driving distractions caused by mobile devices, the distraction by in-vehicle information systems is analyzed rather limited. Cell-phone dialling tasks in cars have been analyzed by Salvucci as well [16]. He generated a model for a priori predictions of total times for different tasks. Stevens et al. published a checklist for the assessment of in-vehicle systems, which contains a questionnaire, instructions and additional supporting information [17, 18]. Nevertheless it remains unclear whether following the proposed procedures leads to systems with better design and supports the identification of design errors. Additionally the European Commission published a statement on the user-interface design principles for in-vehicle information and communication systems [7].

When focussing on the in-vehicle user interface design additional related work has to be considered as well. Green et al. proposed design guidelines for driver information systems by establishing the resumption lag as a factor in predicting an IVIS-style task time [8, 9]. Particular design handbooks such as the European HARDIE report from Ross et al. contain guidelines how information should be to the car driver [13]. Ito et al. analyzed eyes-off-the-road times which are caused by the manipulation of IVIS [11]. Maximum eyes-off times measured in the evaluation were between 4s and 5s.

Libuda presents an example of the potential of multimedia user interfaces [10]. He describes the development of an in-vehicle user interface with different input options: language, manual mode and signs. The in-vehicle presentation of navigational information was analyzed by Narzt et al. They found, that typically either a flat arrow or a virtual bird eye view is used best for visualizing the current position [12].

Presenting information on Head-Up displays (HUD) leads to reduced access costs and increased time with eyes on the road [19]. This way of information presentation can improve the detection of objects in the outside world, lane tracking and velocity control [20].

3 Interaction Schemes

The overview on related work shows that a lot of research has been performed in the field of driver distraction, display technologies and in-vehicle applications. Publications which give a deeper insight into interaction schemes are rarely spread. It is difficult to get a broader overview on user-interface concepts which are implemented in current cars. The underlying interaction schemes play an important role in the estimation of the usability and performance of the in-vehicle user-interface.

We identified different interaction schemes when taking a closer look at seven different in-vehicle user-interfaces: A, B, C, F, L, M and T. As a result of this analysis, several interaction schemes were identified. These are: *integrated interaction, logical connections, information distribution, information presentation in the HUD, menu manipulation, short cuts, independent state transitions*.

3.1 Integrated Interaction Concept

Two different interaction schemes regarding the general interaction concept exist in current cars. In most cars interaction is based on a central multi-functional controller with equal functionality (rotating, shifting and pressing) as shown in Figure 1. In some cars, however, interaction bases on touch screen devices. Both of these interaction concepts show advantages and disadvantages when used in a car. Due to considerations of driver distraction the functionality of touch screen devices is reduced during motion, while the controller based concepts offer the full functionality even during motion.

Furthermore the hard-keys beside the central controllers differ significantly between the different manufacturers. Whereas the central controller concept at user-interface B bases on a controller which can be pushed pressed and rotated, the user-interface A includes many additional hard keys. A composition of these into controller concepts can be found at user-interface M as shown in Figure 1.

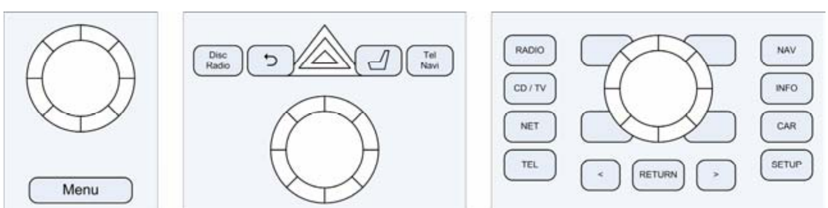
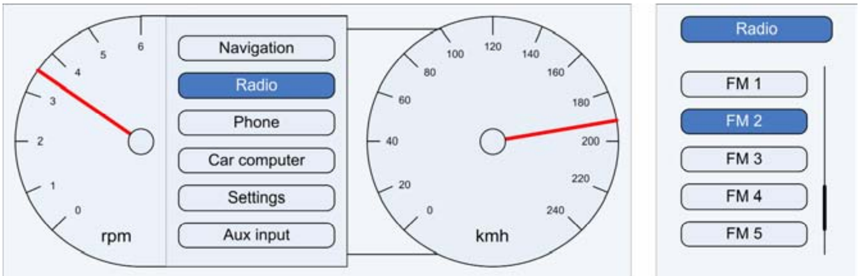


Fig. 1. The integrated interaction concepts at user-interface B (left), user-interface M (middle) and user-interface A (right) base on a multi-functional controller and one or more additional buttons

3.2 Logical Connections

The existence or absence of a logical connection between the central information display (CID) and the digital instrument panel (DIP) are two further interaction schemes which are implemented in current user-interfaces. Some concepts connect the CID and DIP logically as shown in Figure 2a, the modification of the CID's system state



(a)

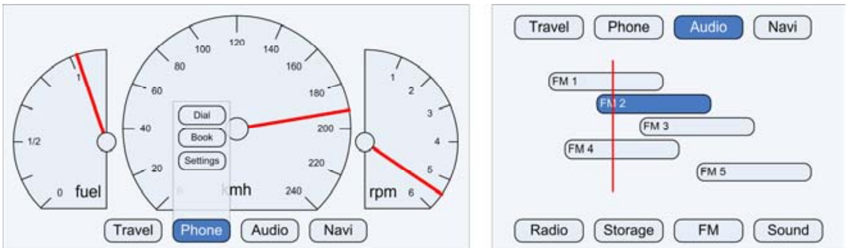


Fig. 2. (a). The digital instrument panel (left) and the central information display (right) are connected logically at user-interface F. **(b).**The digital instrument panel (left) and the central information display (right) are **not** connected logically at user-interface M.

changes the DIP's system state and vice versa. Most current cars, however, use two completely independent system states as shown in Figure 2b.

3.3 Information Distribution

The information distribution across the different display areas in the cockpit follows two different user-interface interaction schemes. The first interaction scheme includes the equal distribution of all information on all available displays, typically CID and DIP. In the second interaction scheme one display is the dominant while the other display only provides sparse information as shown in Figure 3. The CID as well as the DIP is used as the central display in current user-interface concepts for cars.

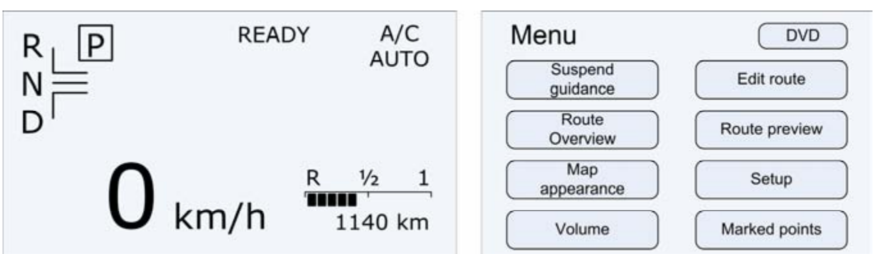


Fig. 3. In the digital instrument panel (left) very sparse information is presented whereas in the central information display (right) extensive information is available at user-interface T

3.4 Information Presentation in the HUD

The introduction of HUDs for cars leads to new interaction schemes for the information distribution between the DIP and HUD. One interaction scheme is the redundant visualization of the most relevant information in the DIP and in the HUD. The relevant information is not distributed between these two displays; it is duplicated as shown in Figure 4. The other interaction scheme contains the consistent distribution of information which leads to the removal of information from the DIP.

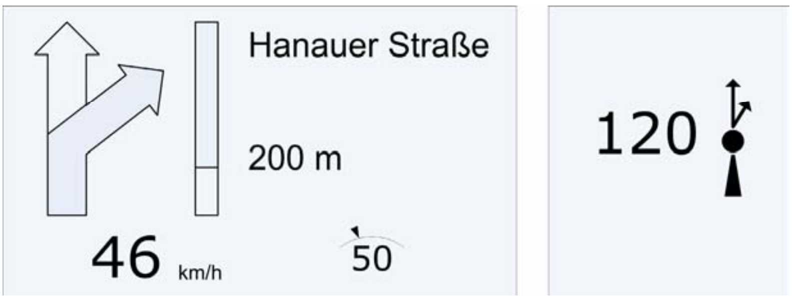


Fig. 4. In the head-up display at user-interface B (left) more information is presented than in the head-up display at user-interface C (right)

The concept of user-interface B contains the presentation of important detailed information; the concept at user-interface C is limited to speed information and a rather schematic navigation hint. Due to the fact that the information at user-interface B is quite detailed the driver has to look on the DIP less frequently.

3.5 Menu Manipulation

Two different interaction schemes for the manipulation of menus exist. In some cars the main menu is realized completely in software. No hard keys for the direct access of menu items are available. In the contrary interaction scheme all items in the main menu are represented by hard keys, the main menu is built in hardware.

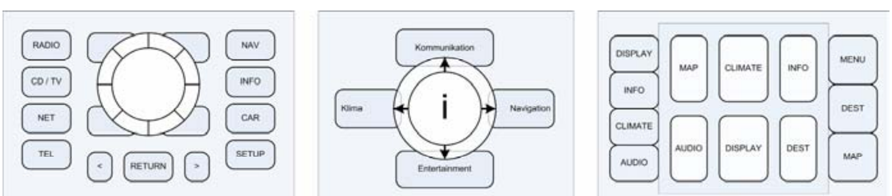


Fig. 5. In user-interface A the main menu is represented by hard keys (left), in user-interface B (middle) the main menu is completely realized in software, and in user-interface T (right) the main menu is represented by hard keys at the side of the screen (dark buttons) as well as on the screen (light buttons)

In some current cars a combination of these two interaction schemes exists, the menu items can be selected by a soft menu as well as by a hard menu. Figure 5 shows the different menu types; User-interface A uses a menu with hard keys, user-interface B uses a soft menu and user-interface T uses a combination of both principles.

3.6 Short Cuts

Short cuts are a common interaction scheme for accessing frequently used functionality more easily. Two different interaction schemes are implemented in current cars. Some cars are equipped with a large number of controls for the direct access of frequently used functionalities. Other cars, however, use short cut controls which can be defined freely by the user as shown in Figure 6.

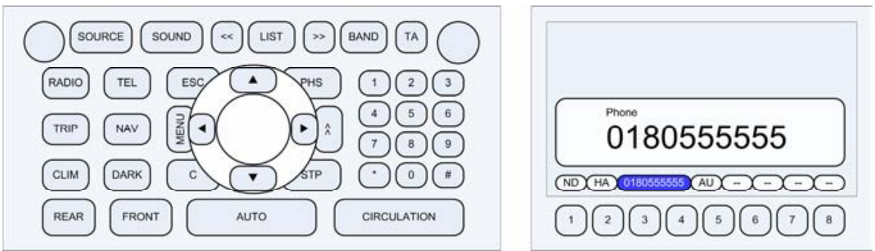


Fig. 6. In the shortcut concept at user-interface C a large number of controls for direct access is provided (left), whereas in the dynamic shortcut concept at user-interface B (right) only a limited amount of dynamic shortcuts is available

3.7 Independent State Transitions

Distraction of the driver's attention is always an issue when discussing different interactive schemes for user-interfaces in cars. Especially common interaction schemes such as returning to a neutral system state have an influence on the distraction of the driver's attention.

In some cars the system returns after certain timeout to the initial state if no further interaction has been performed, as shown in Figure 7. Consequently this concept

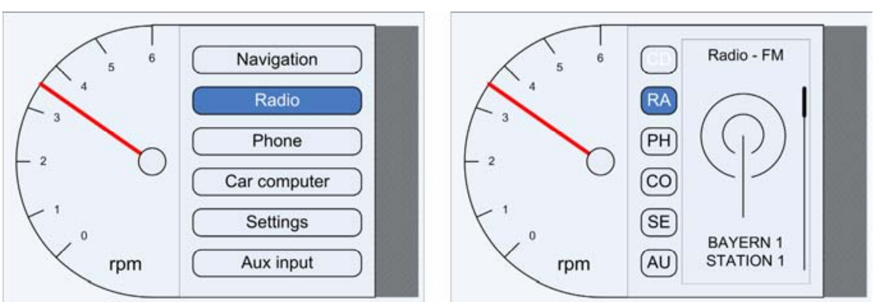


Fig. 7. The user-interface F automatically switches from the menu (left) to the initial state after a certain timeout (right)

forces the driver to perform his task quite fast – if he wants to continue his task at the same point at which he was interrupted. Besides an increase of the interaction times the distraction of the driver might increase as well.

4 Evaluation

Ross et al. give recommendations for the evaluation of IVIS. They state that small-scale expert evaluations in a task-based context lead to good results [14]. Since a rigorous and comprehensive evaluation of technology is quite expensive, the proposed method was used in our evaluation as well.

In our expert-review a group of 7 experts evaluated seven different user-interfaces: A, B, C, F, L, M and T. First of all we tried to get an impression of the usability of the different in-vehicle user-interface with the SUS (system usability scale) test [21]. The results of the SUS are shown in Figure 8 / left. The small sample size made it impossible to interpret the result statistically. We used this SUS test to get an initial estimation of the usability without explicitly distinguishing between usable and less usable in-vehicle interfaces. The test revealed, however, that there is still room for improvement in all user-interfaces, because none of the user-interface is clearly above 50 points (which means that the users could not decide between the two antipoles *user-interface is highly usable* and *user-interface is not usable at all*). The workload was measured by the SEA test [22]. The users performed two tasks: manipulation of the radio (Figure 8 / middle) and of the navigation system (Figure 8 / right).

Again these tests reveal room for improvement; whereas the workload of the radio manipulation (selecting a radio station and changing the volume) was not very high, the manipulation of the navigation system (entering a destination) was rather high.

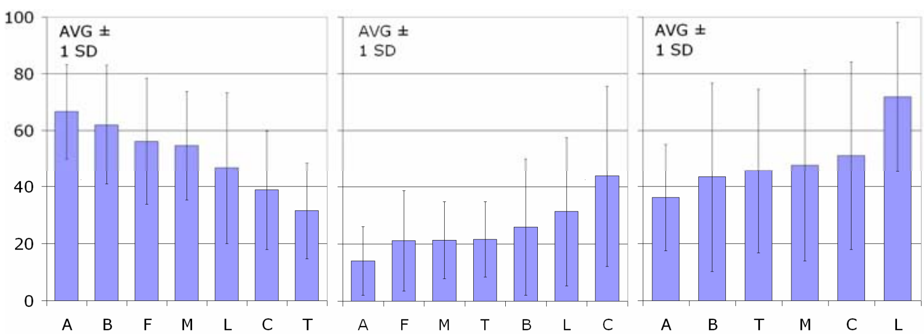


Fig. 8. The usability of the different user-interfaces (left) was evaluated by the SUS-Test, the cognitive workload of the radio manipulation (middle) and the manipulation of the navigation system (right) were evaluated by the SEA-Test

To get an impression of the suitability of the different interaction schemes in the in-vehicle user-interface context, we performed a more specific HMI test from [15]. Whereas SUS and SEA are general tests for the evaluation user-interfaces, the HMI-test focuses on user-interfaces in vehicles. This HMI test is suitable to evaluate numerous aspects of in-vehicle user-interfaces. We selected the aspects, which are connected with the identified interaction schemes (regarding form and content): *occlusion, visiblity, grouping, shortcuts, overview, layout, design, consistency* and *cancelling*. Some of these aspects were evaluated separately for each display (CID, DIP, HUD). The user had to rate each attribute of the user-interface from 1 (very poor) to 5 (very good).

Table 1. In the HMI test we focused on *occlusion, visiblity, grouping, shortcuts, overview, layout, design, consistency* and *cancelling*. The users rated from 1 (very poor) to 5 (very good). The first value shows the mean, the second value in brackets shows the standard deviation.

		C	A	B	T	M	F	L
No occlusions		**3,9 (1,1)**	3,6 (1,8)	3,5 (1,5)	**2,8 (1,4)**	3,6 (1,3)	3,6 (1,3)	3,7 (1,4)
Visible and within reach		**2,7 (1,3)**	3,1 (1,2)	**4,4 (0,7)**	3,1 (1,4)	4,0 (1,0)	3,7 (1,0)	3,8 (1,5)
Logical grouping		**2,7 (1,0)**	**4,1 (1,0)**	3,8 (0,9)	3,0 (1,2)	3,9 (0,8)	3,0 (1,6)	3,7 (1,4)
Spatial grouping		3,1 (1,2)	3,9 (1,0)	3,9 (1,0)	3,1 (1,2)	**4,1 (0,6)**	**3,0 (1,0)**	3,5 (0,8)
Shortcuts		**2,9 (1,2)**	**3,9 (1,4)**	3,8 (1,3)	3,1 (1,0)	3,4 (1,1)	**2,9 (1,2)**	3,8 (0,4)
Overview	DIC	3,7 (1,0)	4,4 (0,7)	4,5 (0,8)	**3,6 (1,4)**	**4,7 (0,5)**	3,7 (1,0)	4,0 (1,5)
	CID	3,0 (1,0)	3,9 (0,6)	3,4 (0,8)	**2,4 (1,1)**	**4,0 (0,5)**	2,6 (0,9)	3,5 (0,8)
	HUD	**4,0 (1,0)**	0,0 (0,0)	**4,9 (0,4)**	0,0 (0,0)	0,0 (0,0)	0,0 (0,0)	0,0 (0,0)
Functionality from design	DIC	**2,3 (0,8)**	**3,9 (1,0)**	**3,9 (1,0)**	2,7 (1,2)	3,4 (0,9)	2,4 (1,0)	3,7 (1,0)
	CID	**2,9 (1,1)**	**4,1 (1,0)**	3,9 (1,0)	3,3 (0,9)	3,6 (1,2)	3,6 (0,9)	3,2 (1,5)
Interaction from design	DIC	**3,0 (1,1)**	**4,5 (0,8)**	3,9 (0,7)	4,0 (0,6)	**4,5 (0,5)**	3,9 (1,1)	3,7 (1,4)
	CID	**3,3 (1,0)**	3,8 (0,9)	4,0 (0,9)	4,0 (0,8)	**4,1 (0,7)**	3,8 (1,1)	4,0 (1,1)
Similar screen layouts	DIC	3,5 (0,6)	3,7 (1,0)	3,8 (0,8)	**2,5 (0,7)**	**3,9 (1,0)**	3,7 (1,0)	3,0 (0,7)
	CID	3,7 (0,8)	**3,9 (1,0)**	**3,9 (1,0)**	**2,4 (0,5)**	3,8 (1,1)	3,3 (1,0)	3,7 (0,8)
Consistent interaction concept	DIC	3,6 (0,9)	**4,4 (0,7)**	3,8 (0,8)	3,5 (0,7)	4,3 (0,7)	3,6 (1,3)	**3,0 (0,9)**
	CID	3,1 (0,9)	3,8 (1,5)	**3,9 (0,8)**	2,8 (1,0)	**3,9 (1,0)**	**2,6 (1,8)**	3,2 (1,3)
Cancelling of settings	DIC	3,2 (1,1)	**4,0 (0,9)**	3,7 (0,8)	3,8 (0,4)	3,6 (1,3)	**2,7 (0,8)**	3,8 (0,8)
	CID	3,3 (1,1)	**3,8 (1,3)**	3,1 (0,9)	**3,0 (1,1)**	3,1 (1,3)	**3,0 (1,0)**	3,2 (1,3)

5 Results and Discussion

When taking a closer look at the lowest and highest values in each category in Table 1 (these values are written bold), we were able to connect these results with the interaction schemes identified above.

The *occlusions* occurred most often at user-interface T (touch screen concept) whereas they occurred quite seldom at user-interface C (central controller concept). A large number of hard keys made it quite difficult for the driver to see the right key and reach it easily. Consequently the visibility and accessibility of the hard keys in the user-interface C (static shortcut concept) was rated rather poor, the visibility and accessibility of user-interface B (dynamic shortcut concept) was rated best. The spatial grouping of the two displays and the logical connection of DIP and CID was rated poor for user-interface F. The cars with no logical connection of the displays (user-interface A and M) were rated best regarding the logical and spatial connection. The shortcut concept at user-interface C (a hard key for every function) was rated quite poor, whereas the shortcut concept at user-interface A (a hard key for each menu) was rated best. The overview was best at user-interface M, which uses a balanced information distribution between CID and DIP. With user-interface T the users lost the overview, caused by the combination of a rather sparse DIP and an overloaded CID. Deducing functionality and way of interaction from the design worked best at user-interface B (single controller) and worst at user-interface C (many different controllers with different functionality and way of interaction). The information presentation in the HUD was rated best at user-interface B (detailed information in the HUD) as opposed to the HUD at user-interface C which offers only limited information (speed and navigation hints). The user-interface T was rated poor regarding the similar screen layouts, which is a consequence of the redundant menu structure (soft menu and hard key menu). The menu manipulations on basis of hard keys (user-interface A) and on basis of a soft menu (user-interface B) were both rated equally well. Cancelling settings was most difficult with user-interface F where independent state transitions are performed after a certain timeout. User-interface A contained the best concept for aborting interactions by using a hard key for the cancelling of interactions.

The analysis of the questionnaire revealed the differences between the HCI models in the different cars. The questionnaire then qualified the different models by showing advantages and disadvantages in interaction. Through the analysis we have the opportunity to identify how different HCI models fit together and can get integrated into one common concept to reduce diversity and complexity of HCI in cars. These results enable research to gain insight in opportunities for highly combined and integrated IVIS systems for optimized driver workload and preference.

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References

1. Ablassmeier, M., Poitschke, T., Rigoll, G.: A new approach of a context-adaptive search agent for automotive environments. In: CHI 2006 extended abstracts on Human factors in computing systems, pp. 1613–1618 (2006)
2. Burnett, G.E.: Usable vehicle navigation systems: are we there yet? In: Proceedings of Vehicle Electronics Systems 2000, European Conference and Exhibition, Leatherhead, UK (2000)
3. Burnett, G.E., Porter, J.M.: Ubiquitous computing within cars: designing controls for non-visual use. International Journal Human-Computer Studies 55, 521–531 (2001)
4. Burnett, G.E., Summerskill, S.J., Porter, J.M.: On-the-move destination entry for vehicle navigation systems: Unsafe by any means? Behaviour & Information Technology 23(4), 265–272 (2004)
5. Campbell, J.L., Richman, J.B., Carney, C., Lee, J.D.: In-vehicle display icons and other information elements. Guidelines, Federal Highway Administration, vol. I (2004)

6. Chittaro, L., De Marco, L.: Driver Distraction Caused by Mobile Devices: Studying and Reducing Safety Risks. In: Proceedings 1st International Workshop Mobile Technologies and Health: Benefits and Risks (2004)
7. Godthelp, H., Haller, R., Hartemann, F., Hallen, A., Pfafferott, I., Stevens, A.: European Statement of Principles on Human Machine Interface for In-Vehicle Information and Communication Systems (May 1998)
8. Green, P.: Estimating Compliance with the 15-Second Rule for Driver-Interface Usability and Safety. In: Human Factors and Ergonomics Society Annual Meeting Proceedings, Surface Transportation, pp. 987–991 (1999)
9. Green, P., Levison, W., Paelke, G., Serafin, C.: Preliminary human factors design guidelines for driver information systems, Tech report: FHWA-RD-94-087. US Government Printing Office, Washington, DC (1995)
10. Libuda, L.: Improving Clarification Dialogs in Speech Command Systems with the Help of User Modeling: A Conceptualization for an In-Car User Interface. In: GI-Workshop ABIS-Adaptivität und Benutzermodellierung in interaktiven Softwaresystemen (2001)
11. Ito, T., Miki, Y.: Japan's safety guideline on in-vehicle display systems. In: Proceedings of the Fourth ITS World Congress, Brussels, Belgium, VERTIS (1997)
12. Narzt, W., Pomberger, G., Ferscha, A., Kolb, D., Müller, R., Wieghardt, J., Hörtner, H., Lindinger, C.: A New Visualization Concept for Navigation Systems. In: Stary, C., Stephanidis, C. (eds.) UI4ALL 2004. LNCS, vol. 3196, pp. 440–451. Springer, Heidelberg (2004)
13. Ross, T., Vaughan, G., Engert, A., Peters, H., Burnett, G., May, A.: Human factors design guidelines for information presentation by route guidance and navigation systems. CEC DRIVE II Project V2008 HARDIE, Deliverable 19, May 1995, 79 p. (1995)
14. Ross, T., Burnett, G.: Evaluating the human-machine interface to vehicle navigation systems as an example of ubiquitous computing. International Journal of Human-Computer Studies 55(4), 661–674 (2001)
15. Rottner, R.: Entwicklung einer praxistauglichen Methode zur Relativbewertung von modernen Anzeige- und Bedienkonzepten im Kraftfahrzeug, Diploma Thesis, Technische Universität München (2002)
16. Salvucci, D.D.: Predicting the effects of in-car interface use on driver performance: an integrated model approach. International Journal of Human-Computer Studies 55(1), 85–107 (2001)
17. Stevens, A., Board, P.A., Quimby, A.: A Safety Checklist for the Assessment of in-Vehicle Information Systems: Scoring Proforma, Project Report PA3536-A/99, Crowthorne, UK, Transport Research Laboratory (1999)
18. Stevens, A., Quimby, A., Board, A., Kersloot, T., Burns, P.: Design Guidelines for Safety of In-Vehicle Information Systems, TRL Limited (2004)
19. Sojourmer, R.J., Antin, J.F.: The effects of a simulated head-up display speedometer on perceptual task performance. Human Factors 32(3), 329–339 (1990)
20. Weintraub, D.J.: Human Factors Issues in Head-Up Display Design: The Book of HUD Descriptive, State-of-the-art report, Dayton University Ohio Research Institute (1992)
21. Brooke, J.: SUS: A quick and dirty usability scale. In: Jordan, P., Thomas, B., Weerdmeester, B., McClelland, I. (eds.) Usability evaluation in industry, pp. 189–194. Taylor & Francis, London (1996)
22. Eilers, K., Nachreiner, F., Hänecke, K.: Entwicklung und Überprüfung einer Skala zur Erfassung subjektiv erlebter Anstrengung. Zeitschrift für Arbeitswissenschaft 40(4), 215–224 (1986)