Digitalisation in the infotainment: User needs and requirements – an explorative approach.

Anna Pätzold[*1], Rami Zarife[2], Michael Wagner[2], and Josef F. Krems[3]

[1, 2] EE Core Infotainment & Program Management, Opel Automobile GmbH, Rüsselsheim, Germany
[3] Cognitive and Engineering Psychology, Institute for Psychology, Technische Universität Chemnitz, Germany
[*]anna.paetzold@opel.com

Abstract:
In order to understand drivers' needs and requirements in extending infotainment functions, an explorative approach, consisting of creativity workshops, a focus group and an online survey was pursued. In the creativity workshops and the focus group, spending the driving time usefully was identified as the main motivational factor for drivers to engage into their mobile devices while driving. Nonetheless, they did not want to be distracted. The need to be informed about the environment, including participants' social network and traffic circumstances, was highlighted. The online survey found interaction effects between modality of secondary task and driving situation. Context factors were found to have different effects on the willingness to engage in the secondary task in question. Especially for the context factor *street type*, the demanded secondary task modality effect showed the highest impact. The cascade of the explorative approach provided a feasible way to obtain a comprehensive understanding of driver needs and requirements in extending infotainment functions.

1. Introduction

Due to the digital revolution, new and extended functions will be available both on smartphones and in the in-car infotainment systems [1, 2], increasing the amount of information provided to the driver [3].

As a visually-manually focused task [ibid.], driving interferes with any other task demanding the same modalities [4]. According to the Task-Capability-Interface-Model, an imbalance between a driver's capabilities and the task demands can lead to a loss of control [5].

1.1. Engagement in secondary tasks while driving

Although negative effects of engagement into secondary tasks on reaction times [6], visual monitoring [7] and vehicle control [8, 9], including speed and lane keeping, were found, and the usage of smartphones while driving is banned in many countries, drivers today use their mobile phones and personal digital assistants more frequently while driving [10, 11, 12].

The recent US-American naturalistic driving study SHRP2 found an increase in crash risk due to operating in-vehicle devices by an odds ratio of 2.5, leading to 3.53 % of all observed accidents [13]. Further, the usage of nomadic devices while driving was found to have an odds ratio of 3.6 causing 6.40 % of all observed accidents [ibid.]. SHRP2 also found distracting activities, such as smartphone usage, to occur much more frequently than drivers' impairments, such as drowsiness [14].

Equally, the European naturalistic driving study UDRIVE found the most distracting activities to be primarily located in the middle console [15]. From all the observed secondary tasks, mobile phone usage was the most frequent executed and had the longest task engagement duration [16].

1.2. Motivations for engaging in secondary tasks

As identified in a review [17], the main key themes for engagement in distracting activities in distraction research are perceived risk and incidence of use. Though, parameters influencing perceived risk are still missing.

As the drivers' needs change depending on the context [18, 19, 20, 21], one motivation for engaging in secondary tasks while driving can be the context. Further, the need for information on the environment, such as traffic and communication were found as influencing factors [22].

1.3. Aim and scope of the current research

In order to understand driver's needs and requirements in extending infotainment functions, an explorative approach, consisting of creativity workshops, a focus group and an online survey, was pursued (Fig. 1).

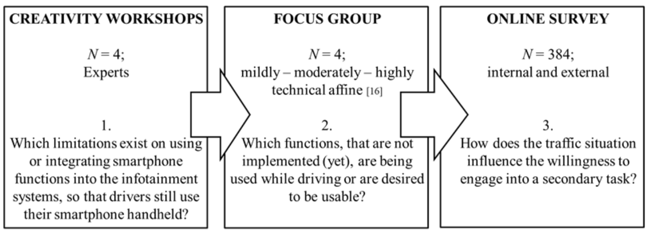

Fig. 1. *Methodology of the explorative approach*

2. Creativity Workshops

2.1. Research Questions

Phone projection applications, such as AndroidAuto and Apple CarPlay, give the possibility to use specific smartphone functions while driving, intending to make the handheld use of the smartphone while driving superfluous.

Still, some smartphone functions are not yet implementable into the infotainment systems or are not suitable for usage while driving. In order to investigate these factors, the limitations of smartphone functions as well as potential HMI characteristics were explored.

2.2. Method

Two creativity workshops were conducted with each $N = 4$ internal experts in infotainment HMI engineering. The first workshop used the Double Reverse Technique [23, Fig. 2], and was intended to identify elements of smartphone functions that make these functions uncomfortable to use or restrict them from using while driving. Smartphone functions were categorised into communication, navigation, media, browsing and other (Table 1).

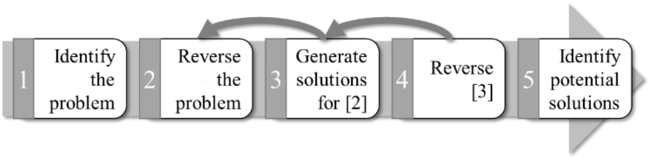

Fig. 2. *Double Reverse Technique [23]*

Table 1. Smartphone functions.

	Examples
Communication	Messenger, Calls, Address Book, Social Media,…
Navigation	Traffic information, POIs, Favorites,…
Media	Streaming Services, Playlists, Gallery,…
Browsing	Search, Shopping, Finances,…
Other	Clock, Calendar, Notes,…

The second workshop used the Brute Think Technique [ibid.,Fig. 3] to identify HMI characteristics that can be used to implement these solutions.

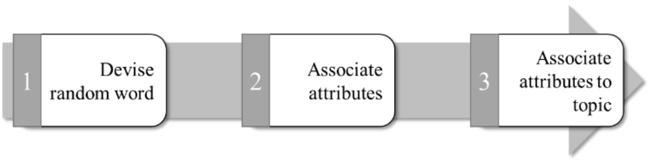

Fig. 3. *Brute Think Technique [23]*

2.3. Results

Selected results of both workshops are shown in Table 2.

Table 2. Results Creativity Workshops.

	Problem	Double Reverse Result	Brute Think Result
Communication: Messenger	Long message being read-out or displayed	Interruptible reading-out	Highlighting of relevant information
Navigation: Points-of-Interest	Irrelevant POIs	Status-based selection: empty gas tank, gas stations at top of the list	Selection of nearby POIs based on user behaviour
Media: Playlists	Many playlists to select from		Tiles for each playlist
Browsing: Search	High input quantity	Use speech	Minimize data entry
Other: Calendar	Not synced	Adapt Address Book, Navigation, …	

2.3.1 Smartphone Functions. For the in-car use while driving, too much information is shown. In addition, many input steps are necessary to execute the intended function. Using the smartphone while driving is uncomfortable; not only because of hand position, the position of the centre-stack display, or the provoked distraction, but also because of the cognitive dissonance perceived by drivers. Since drivers are aware of the distracting effects of smartphone usage, they experience a conflict between their need to engage in the smartphone and their need to avoid distraction while driving.

2.3.2 HMI Characteristics. In order to address these issues, the HMI can be changed by integrating new elements e.g. highlighting information, introducing shortcuts to recently, frequently or intended to-be-used functions, change the modality of the input and output. Further, position of the shown information can be adapted between and within displays.

2.4. Conclusion

Since the overall issue is the amount of displayed information, the infotainment system should be able to provide the same content with less characters. Since the driving task is visual-manual focussed, the secondary task modality should potentially load on another modality, such as cognitive-auditory.

3. Focus Group

3.1. Research Questions

A focus group [24] was conducted to further investigate driver's motivation to use a smartphone while driving. It was of interest (1) which mobile devices and functions participants currently use while driving, (2) which functions they would like to be able to use in their cars besides mobile devices' functions, (3) which strategies they use to avoid distraction and (4) potential design solutions to improve usage.

3.2. Method

N = 4 participants were chosen out of the company's internal participants pool based on their technical affinity. Technical Affinity was assessed beforehand via an online screener using the Questionnaire on Technical Affinity (TA-EG [25]). According to the distribution, one participant of the 33rd, one of the 66th, and two of the upper percentile participated. Three male and one female participants took part, with a mean age of *M* = 43.5 years (*SD* = 13.08, Range = 26-54 years).

The first part consisted of participants individually filling a worksheet asking for currently in-car used nomadic devices, desired functions, strategies to avoid distraction and potential designs to improve usage. The second part consisted of an open discussion, debating an order and requirements for preferred implemented features.

The focus group was recorded on video. Participants agreed on video recording before filling the online survey. The recorded video was transcribed using ELAN 4.9.4 and FreeQDA.

3.3. Results

3.3.1 Currently in-car used nomadic devices. Besides the less technical affine participant, participants stressed the wish to use the smartphone while driving to communicate and to navigate, especially when their in-car navigation systems did not provide live traffic.

Communication included phoning via Bluetooth (*n* = 4), dialling via speech recognition (*n* = 2), reading and typing messages (*n* = 2), speech-based texting (*n* = 2).

Smartphone-based navigation was used by three participants and by two of them via phone projection applications, such as AndroidAuto and Apple CarPlay. It was also used on familiar routes to be informed about live traffic.

One participant also used Music Streaming on a daily basis via AndroidAuto.

3.3.2 Desired functions. Speech recognition systems are currently used and desired to provide natural language understanding (*n* = 3). Further, one participants wished to be able to listen to and record voice messages while driving.

Also, a synchronisation between personal mobile devices and the infotainment system regarding data and files was mentioned (*n* = 1). As a part of their daily routine, the car shall be able to act as an office provider.

Further, participants wished for a more stable internet connection via W-LAN in their cars (*n* = 2).

3.3.3 Strategies to avoid distraction. The technically less affine participant mentioned to avoid controlling any infotainment function while driving. Both the technically less and moderate participants stated to put their smartphones out of reach while driving, and only using it in traffic jams (*n* = 1).

In order to monitor, the technically moderate and high affine participants mentioned to switch their gazes more frequently between infotainment displays and the traffic scene.

Phone projection applications were mentioned to avoid distraction (*n* = 2), especially when used with speech recognition (*n* = 1). Smartphone-based functions like navigation and playlists were set up before starting to drive (*n* =2).

If the smartphone was used while driving, it was held in the right hand next to the steering wheel or the hand was laying on the right thigh.

3.3.4 Potential designs to improve usage. Three participants were experienced with Head-up displays and mentioned the advantages, as they did not need to take their gazes far from the traffic scene. Regarding input devices, participants were indecisive on rotary push, touchscreens, touchpads and steering wheel controls. The ability to control them blindly was highlighted. They agreed on the importance of a haptic feedback and a system that requires few input steps, by i.e. providing suggestions.

Further, the technically high affine participants mentioned new input technologies such as eye tracking, to be an interesting and compelling approach.

Participants reached consensus on the need for a minimized distractive system that still fulfils their needs. Therefore, the usage of the infotainment system shall be easy and intuitively understandable. That is, interaction methods shall be indicated clearly and unambiguously. Easiness and efficiency were stated to be most important. As an example, one participant said *"there are several easy things, I press a button instead of telling the system to warm up the ventilation"*. Another one reported problems with speech recognition, as he has *"never yelled at a system that often before"*.

Further, they wished to have adapting or customizable display and control elements with their most frequently used function. Especially when a car is shared, an automatic adaptation of infotainment and vehicle parameters, such as seating, was mentioned (*n* = 3).

3.3.5 Open discussion. The two technically less and moderate affine participants mentioned avoidance of smartphone use while driving, since their cars' infotainment systems does not have phone projection applications. The other two, technically high affine participants, use AndroidAuto or Apple CarPlay daily, but still missed some functionalities. Therefore, they intentionally disconnect their smartphones due to restricted functions, i.e. scrolling down long lists, or not implemented functions, i.e. recording voice messages.

Further, one participant mentioned to *"use the smartphone to receive, read and write text messages, which is not optimal in every driving situation"*. Participants agreed that one main factor for the decision whether or not to use their smartphone while driving was the driving situation. One participant stated, that he rather engages into a secondary tasks when he can foresee the upcoming situation. Driving on a highway with moderate traffic seems more anticipative to him than driving in a city scenario.

3.4. Conclusion

It was especially difficult for participants to think of further functions they would like to use while driving. Although no needs for future functions could be retained from the focus group, it gave a good impression on functionalities that are designed unsuitably or even irritating.

Supporting [22] findings, the need to be informed about the environment, including participant's social network and traffic circumstances, was empathised and stated to contradict with the need to not be distracted.

The need to be informed about the social and traffic environment were the main motivational factors for using the smartphone while driving.

4. Online Survey

4.1. Motivation and Research Questions

Although interfering effects in dual-task execution can be explained using the Multiple Resource Theory [4], little research on the interaction of driving situation variables and secondary task execution was done.

In a survey study, Ferreira et al. [53] identified drivers to be least likely to engage in their phones on city roads, but rather on highways. Young and Lenné [55] found in an online survey, that secondary tasks while driving were avoided in bad weather, winding roads, heavy traffic or night. Supporting these findings, Britschgi et al. [52] identified bad weather, heavy traffic and city roads to influence the willingness to use a phone while driving. Hancox et al. [54] found drivers decision (not) to engage in a phone task, such as placing or answering calls and sending or reading texts, to be depended both on the perceived demands of the roadway and the phone function. Especially placing or answering a phone call was of low willingness in high demanding driving situations.

Regarding driving situation complexity, Fastenmeier [27] found street characteristics to have the highest impact on driving situation complexity, whereas traffic density and visibility were identified as weighing factors.

Horberry et al. [26] found complex driving situations to lead to compensatory behaviour and higher perceived distraction when simultaneously executing an in-vehicle entertainment task or talking on the smartphone. According to Lerner et al. [28], task-related motivations to be dominant decision factors in contrast to driving-related motivations, such as the upcoming driving maneuver.

In UDRIVE it was also found, that the willingness to engage in a secondary task depended on the workload of the task [16]. Contrary to the hypotheses, complex tasks were more likely executed in complex driving tasks and also longer in duration.

As the focus group revealed, the decision on whether or not to engage into a secondary task while driving seems to be depending on the driving situation and the modality of the task, hence, the interaction between the two was the focus for the online survey.

4.2. Method

In order to investigate the effect of the driving situation on the willingness to engage in a secondary task, an online survey was conducted. An online survey was chosen to avoid social desirability by providing anonymity [e.g. 29].

4.2.1 Participants. All participants held a valid driver's license. N = 444 persons participated in the online survey, whereas n = 60 had to be removed due to incomplete data. Participants (23.7 % female) were M = 45.08 years old (SD = 9.57, Range: 20-75 years). They were recruited via the company's internal participants pool, university's student mailing lists and social media platforms. As an incentive, two 25€ Amazon vouchers were drawn among interested non-company participants.

4.2.2 Measures. On demographics, age, gender, driver license possession and year of acquisition, annual mileage and eye vision were asked.

Technical affinity was assessed using the TA-EG [25]. Driving Style was rated on the short version of the Multidimensional Driving Style Inventory [30], adapted to and validated in Europe by [31]. Two items on the wish to use and connect the smartphone with the infotainment system were included [21]. The knowledge on and usage of new media were assessed. Further, the willingness to engage in a secondary task depending on the driving situation was investigated using a choice-based conjoint analysis (CBCA).

4.2.3 Context. Driving situation profiles were generated using the context factors adapted from [18, 21]. A driving situation was defined by street type (city, rural, highway), landscape (flat, hills, trees), traffic density (low, moderate, high), weather (dry, rain, snow) and daytime (day, night) (Fig. 4). See Table 8 in Appendices.

In order to reduce the number of profiles, two orthogonal arrays [32] were combined. For three-step factors, a fractional 3^4 Design [33] or Plan 3 [32] was applied (Table 8), whereas daytime was applied using the first nine columns and first 18 rows of Plan 8 [ibid.]. Profiles were assorted to 18 choice sets using a Balanced Incomplete Design [33, 34]. Participants were randomly assigned to three groups, each being presented six choice sets.

Since spontaneous answers in a low-involvement situation [33, 35] and a low social desirability [36] were required, a CBCA was chosen to assess willingness to engage in a secondary task in a specific driving situation. Participants were asked to choose the one driving situation in which they would not engage in the secondary task. Alternatively, they could choose the none-option of *"I would use the function in all scenarios"*. Whether the task was to be executed on an in-vehicle display or a hand-held device was not of importance. See Fig. 5 for an example of the online survey.

Fig. 4. *Driving situations used in the online survey*

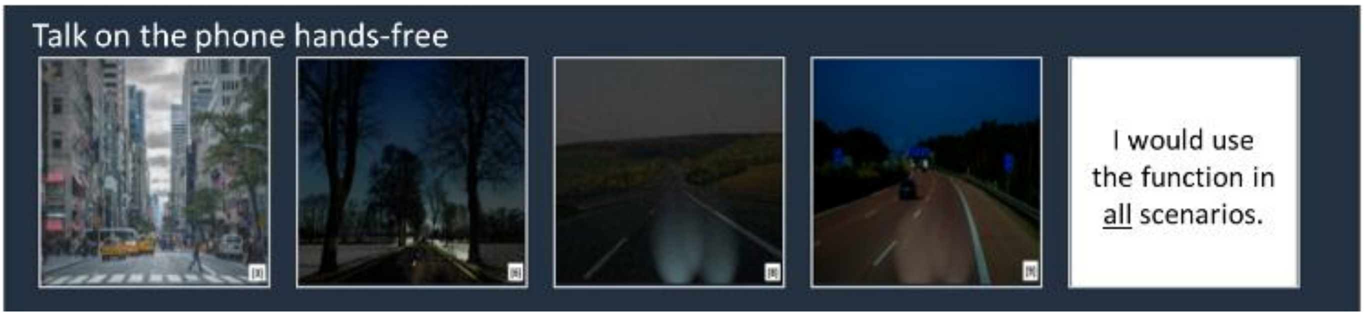

Fig. 5. *Example of the CBCA from the online survey*

4.2.4 Secondary Tasks. Following the Multiple Resource Theory [4] secondary tasks covering the four modalities, both encoding strategies and interaction styles [37] were evaluated. See Table 3 for the six secondary tasks.

Table 3. Secondary Tasks following [4, 37]

Task	Modality	Encoding	Interaction
read a text message	visual	verbal	passive
type a text message	visual-manual	verbal-spatial	active
watch a video	visual-auditory	verbal	passive
talk on the phone hands-free	cognitive-auditory	verbal	active-passive
make a shopping list	cognitive	verbal	active
adjust volume	manual	spatial	active

4.3. Results

4.3.1 Connectivity. The results for the willingness to use content of electronic devices and the wish to connect the smartphone with the in-car infotainment system [21] are shown in Fig. 6 and Fig. 7. Most of the participants want to only consume content without necessarily sharing their experiences and content. Also, most participants want to be able to connect their smartphones with the infotainment system.

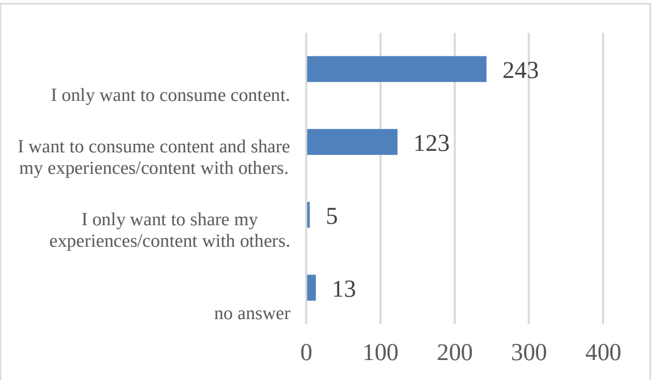

Fig. 6. *Willingness to use electronic devices, N = 384*

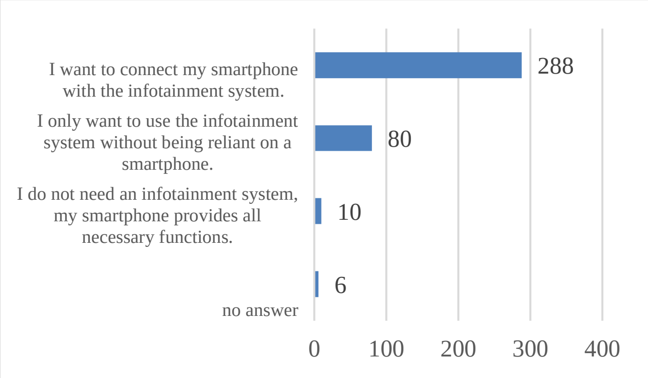

Fig. 7. *Willingness to connect the smartphone and infotainment system, N = 384*

4.3.2 Technical Affinity. In order to control for a normal distribution of technically less, moderately and highly affine participants, percentiles of the TA-EG [25] scores were calculated. For further analysis, technical affinity was split into low (TA-EG score: 9.25-12.55, $n = 124$), moderate (12.6-13.65, $n = 123$) and high (13.65-17.2, $n = 137$).

4.3.3 Driver Profiles. In order to identify driver types, item scores in the short MDSI were multiplied with the adjusted factor loadings, generating factor scores. See Table 4 for results. Driver profiles were extracted by normalizing the factor scores [31], Fig. 8. Ratings of $n = 70$ participants did not exceed the threshold for one driver profile category. In total, 59.55 % of participants ratings did not load on more than one factor of the MDSI, hence, further analysis only took the six driving styles of angry (ANG), risky (RIS), anxious (ANX), dissociative (DIS), careful (CAR) and distress-reducing (DRE) driving into account.

Table 4. Driver profiles, $N = 384$

	ANG	RIS	ANX	DIS	CAR	DRE
n	76	65	70	55	62	56

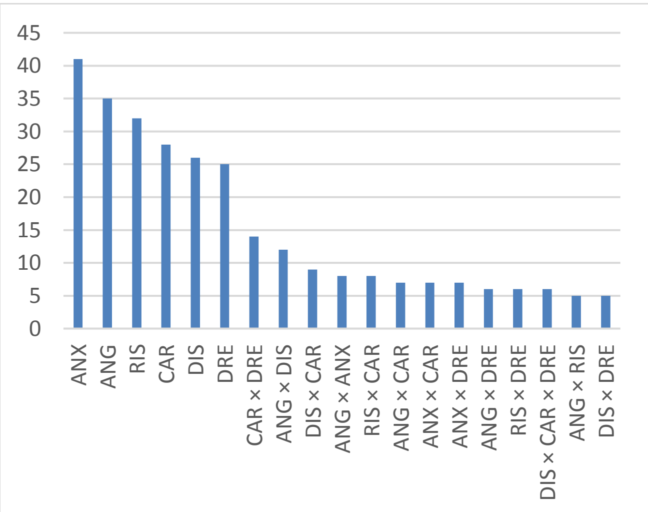

Fig. 8. *Distribution of Driver Profiles MDSI [17], n = 287*

Note: Only Driver Profiles with $n \geq 5$ are shown.

4.3.4 Engagement in secondary tasks. Fig. 9 shows the results of the CBCA on willingness to engage in the secondary task while driving for the driving situation factors. A higher percentage indicates a higher probability of a decision against engaging in the secondary task.

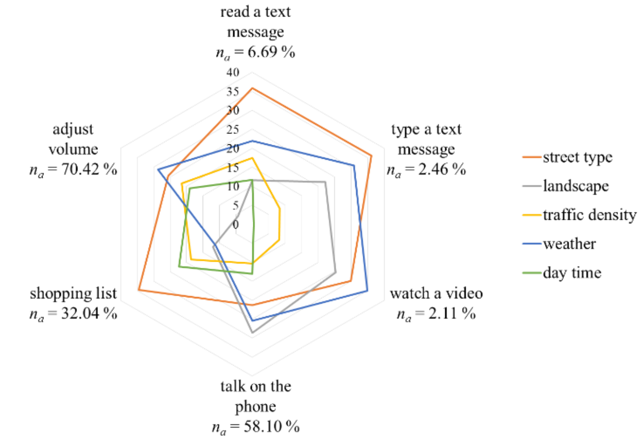

Fig. 9. *Relative importance values of context factors for each secondary task*

Note: n_a describes the percentage of participants willing to use the function in every driving situation.

Relative importance values of the context factors and levels found in the CBCA for the decision against engagement for each secondary task are shown in the following figures 10 - 15. Please find the path-worth utilities in

Table 910, Appendices.

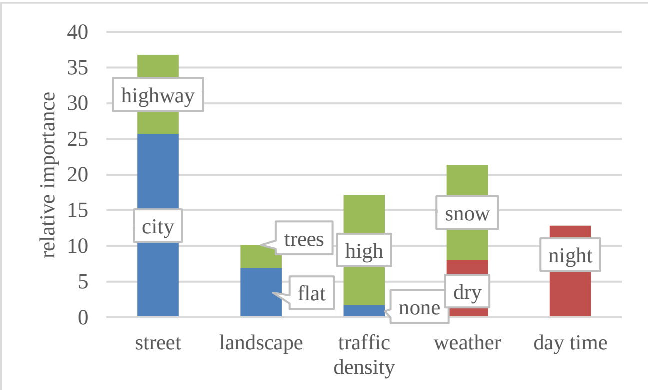

Fig. 10. *Read a text message*

Note: Relative importance for context factors: street 36.79%, landscape 10.12 %, traffic density 17.16%, weather 21.38%, day time 12.84%

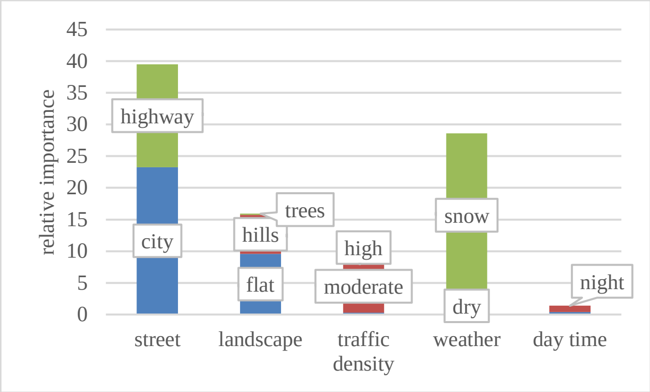

Fig. 11. *Type a text message*

Note: Relative importance for context factors: street 39.52%, landscape 15.93 %, traffic density 12.53%, weather 28.61%, day time 1.38%

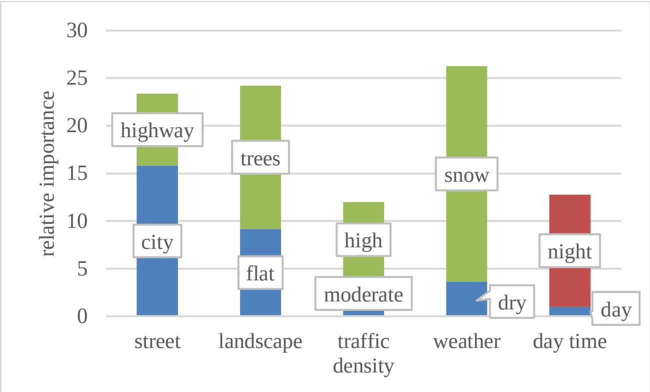

Fig. 12. *Watch a video*

Note: Relative importance for context factors: street 23.37%, landscape 24.21 %, traffic density 11.98%, weather 26.24%, day time 12.77%

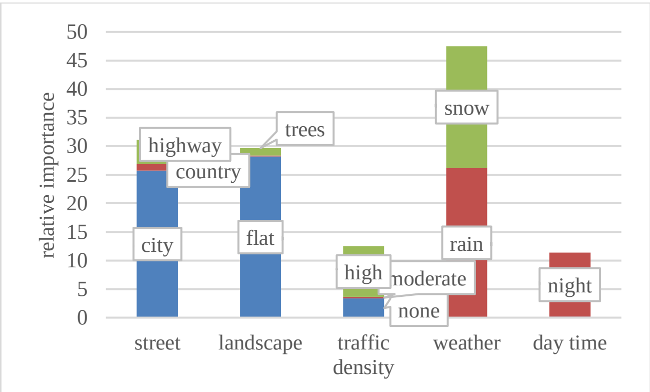

Fig. 13. *Talk on the phone hands-free*

Note: Relative importance for context factors: street 31.11%, landscape 29.66%, traffic density 12.49%, weather 47.52%, day time 11.38%

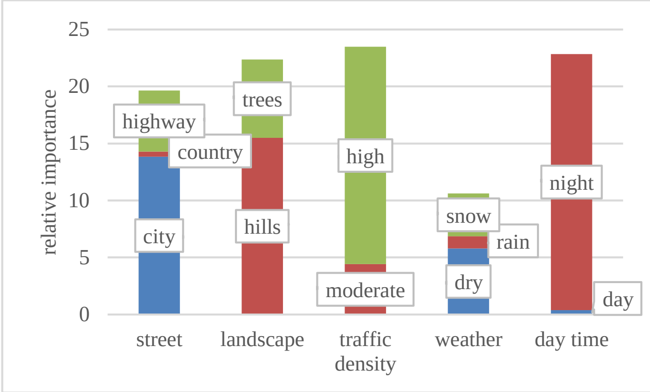

Fig. 14. *Make a shopping list mentally*

Note: Relative importance for context factors: street 19.65%, landscape 22.37%, traffic density 23.48%, weather 10.62%, day time 22.86%

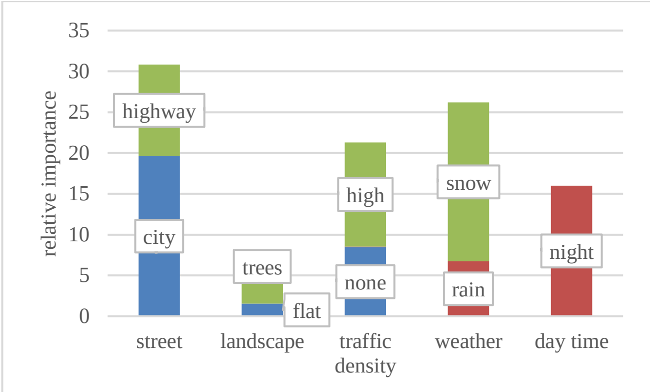

Fig. 15. *Adjust volume manually*

Note: Relative importance for context factors: street 30.82%, landscape 4.78%, traffic density 21.29%, weather 26.19%, day time 15.98%

4.3.5 Clusters. To investigate influence factors on the decision not to engage in a secondary task, hierarchical cluster analyses were calculated for each secondary task [36, 38]. For all secondary tasks, the dendrogram identified two clusters. Cluster A included participants deciding against engaging in the secondary task depending on the driving situation, cluster B included participants willing to engage in the secondary task in every driving situation. Table 5 shows the cluster groups for each secondary task. Driver profiles associated with the clusters are shown in Fig. 16.

Table 5. Clusters for secondary tasks, N = 384

	$n_{Cluster A}$	$n_{Cluster B}$
read a text message	361, 24.1% female	23, 17.4% female
type a text message	374, 23.5% female	10, 20.0% female
watch a video	376, 23.1% female	8, 37.5% female
talk on the phone hands-free	217, 24.4% female	167, 22.2% female
make a shopping list mentally	120, 26.7% female	264, 22.3% female
adjust volume manually	266, 22.6% female	118, 25.4% female

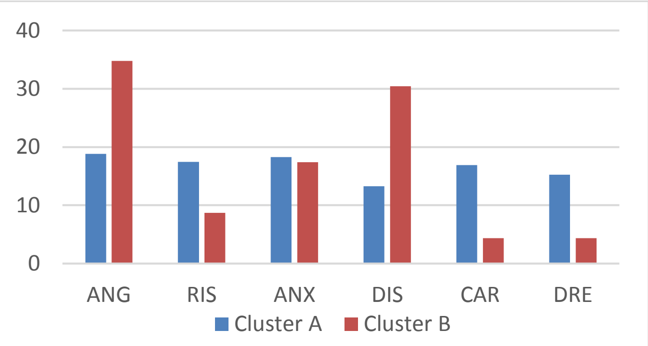

Fig. 16. *Percentages of Driver Profiles for Cluster A and Cluster B, N = 384*

Table 7 shows the effects of the cluster characteristics on the willingness to engage in the secondary task. In the following, significant effects for each secondary task are described in detail.

Read a text message. Participants with a mean age of 40.74 years (SD = 8.49) were more willing to engage in the secondary task in every driving situation than participants of M = 45.36 years (SD = 9.57). Participants willing to read a text message in every driving situation were rather classified as more angry and dissociative drivers and less careful and distress-reducing drivers.

Watch a video. Participants with a higher annual mileage (M = 26 250.00 km, SD = 9 543.14) were more willing to engage in the secondary task than participants with a lower annual mileage (M = 17 816.91 km, SD = 11 191.67).

Talk on the phone hands-free. Participants of M = 44.07 years (SD = 9.51) were more willing to make a hands-free phone call while driving than participants with a mean age of 46.29 years (SD = 9.11). Participants with a higher annual mileage (M = 19 407.69 km, SD = 12 246.64) were more willing to engage in the secondary task than participants with a lower annual mileage (M = 16 585.12 km, SD = 9 489.63).

Make a shopping list mentally. The two clusters differed significantly regarding age, as participants of M = 43.58 years (SD = 10.218) were more willing to engage in the secondary task than participants of a mean age of 45.76 years, SD = 9.19).

Adjust the volume manually. Participants willing to engage into the secondary tasks were 44.43 years (SD = 9.64) on average, whereas participants deciding against the secondary tasks were M = 46.65 years old (SD = 9.07). Participants with a higher annual mileage (M = 18 811.90 km, SD = 11 595.73) would rather engage in adjusting the music volume in every driving situation than those with a lower (M = 16 145.70 km, SD = 10 106.88, F = 1.096, p = .296, η_p^2 = .003).

Table 6. Effects of the identified clusters on the willingness

		Read a text message	Type a text message	Watch a video	Make a phone call hands-free	Make a shopping list mentally	Adjust the music volume
Age	p	.025*	.098	.203	.021*	.038*	.035*
	η_p^2	.013	.007	*.004*	.014	.011	.012
Gender	p	.463	.795	.343	.603	.356	.541
	CC	.037	.013	.048	.027	.047	.031
Annual	p	.296	.277	.035*	.014*	.180	.296
Mileage	η_p^2	.003	.003	.012	.016	.005	.003
Technical	p	.201	.853	.599	.110	.616	.461
Affinity	η_p^2	.004	.000	.001	.007	.001	.001
Driver	p	.034*	.442	.432	.554	.314	.084
Profile	CC	.177	.112	.113	.102	.124	.159

4.3.6 Calculations for driving situations. Over all secondary tasks, the driving situation that raised the highest willingness to engage into any secondary task, independent of its modality, is country road (0.02), flat (0.43), moderate traffic (0.26), and dry weather (0.28) by day time (0.03) with a total utility of 1.02.

Situations that raised the lowest and the highest willingness to engage in the secondary task in question are shown in Table 7.

Table 7. Calculations for willingness to engage in a secondary task

		Street Type	Landscape	Traffic Density	Weather	Day Time	Total utility
read a text message	lowest	Country 0.00	Hills 0.00	Moderate 0.00	Dry 0.00	Day 0.00	0.00
	highest	City 2.06	Flat 0.57	High 0.96	Snow 1.20	Night 0.72	5.51
type a text message	lowest	Country 0.00	Trees 0.02	None 0.02	Rain 0.00	Day 0.03	0.07
	highest	City 1.85	Flat 0.76	Moderate 0.61	Snow 1.34	Night 0.10	4.66
watch a video	lowest	Country 0.00	Hills 0.00	None 0.08	Rain 0.00	Day 0.08	0.16
	highest	City 1.56	Trees 1.62	High 0.88	Snow 1.76	Night 0.93	6.75
Talk on the phone	lowest	Country 0.06	Hills 0.01	Moderate 0.01	Dry 0.00	Day 0.01	0.09
	highest	City 1.6	Flat 1.76	High 0.55	Rain 1.64	Night 0.70	6.25
make a shopping list	lowest	Country 0.06	Flat 0.00	None 0.00	Rain 0.22	Day 0.03	0.31
	highest	City 1.91	Hills 2.10	High 2.21	Dry 1.22	Night 2.19	9.63
adjust volume	lowest	Country 0.01	Hills 0.00	Moderate 0.03	Dry 0.00	Day 0.02	0.06
	highest	City 3.11	Trees 0.53	High 2.63	Snow 3.48	Night 2.32	12.07

4.4. Conclusion

The CBCA showed a secondary task modality effect for the factors and factor levels, indicating that there are relevant differences in the interaction of driving situation and secondary task.

Consistent with Fastenmeier [27], the context factor street type showed the highest impact on the demanded secondary task modality.

Lerner et al. [28] found participants to not attribute particular risk to basic use of smartphone functions, such as dialling, answering, and conversing. Here, *read a text message* and *type a text message* were found to be the least wanted to be executed in every driving situation, whereas *talk on the phone hands-free* was of high willingness.

As Huemer and Vollrath [39] observed, drivers more frequently engage in their smartphones when driving on a highway than when driving in a city. Going hand in hand with [52, 53] findings, drivers were less willing to use their smartphones on city roads. Carsten et al. [16] also found secondary task engagement most frequently on urban roads, and secondly on country motorway. Whereas little secondary task activity was found for rural roads, participants in the online survey were most willing to engage in secondary tasks on rural roads. Overall, country roads under dry weather were assigned the highest willingness to engage in a secondary task. In UDRIVE [16], country motorways in non-adverse weather conditions were identified as the most frequent context for secondary task engagement.

Supporting [52, 55] findings, willingness to engage in secondary tasks under bad weather, heavy traffic and at nights was low for all secondary tasks.

Female drivers were found to more frequently use their smartphones for texting and answering calls [51]. In contrast, [16] found women and men to be equally engaged in mobile phone tasks. No effect for gender was found here. Though, the willingness to engage in a secondary task was influenced by the age, annual mileage and driver profile. As previously found by [29, 40], age had a significant effect on the willingness to engage in some secondary tasks. Here, slightly younger participants were found to be more willing to *read a text message, talk on the phone hands-free*, *make a shopping list mentally* and *adjust the volume manually* in every driving situation. Further, annual mileage was found to influence the decision as well. *Watch a video* and *talk on the phone hands-free* was more likely for participants with a higher annual mileage. Only for *read a text message* an effect of driver profiles was found. Rather angry and dissociative classified drivers were more willing to read a text message in all of the driving situations than less careful and distress-reducing drivers.

5. Implications

Based on these findings, there is no single driving situation that has comparable effects on driver's perceptions whether to engage or not in a secondary task.

Although lock-outs were shown to have a positive effect on driving safety [41], participants of the present focus group reported to use alternatives to operate the restricted functions that are not safe for driving. As in [42], participants potentially experience a loss in autonomy, leading to psychological reactance.

Since the user requirements change over time [43, 44], influenced by the context [18, 19, 21], the user groups are heterogeneous [44] and changes in the environment [44, 45], adaptivity in the HMI is indicated (Fig. 17).

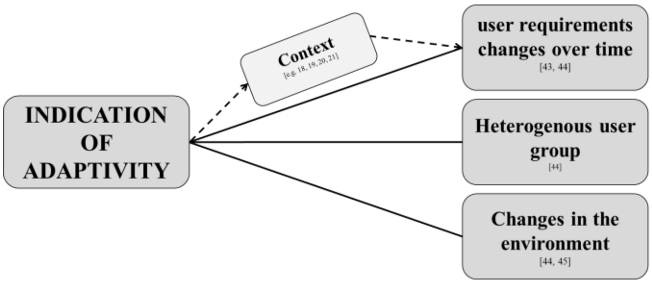

Fig. 17. *Indication of Adaptivity*

Depending on the driving situations, the HMI and warnings should be adapted accordingly. Whereas cognitive-auditory tasks seem to be unproblematic in most traffic scenarios, visual-manual tasks should be reduced in high workload scenarios, such as city drives in rain. Based on the Yerkes-Dodson-Law [46], adapting HMI content should not be reduced in all situations. In low arousing situations, such as country roads with no traffic, the HMI content can contain more information than in higher arousing situations, such as city drives with high traffic density.

Further, the adaptation should be as predictive as the driver's anticipation of the driving situation to provide not only user experience but safety for driving by a higher system understanding. The adaptation shall then follow the hysteresis principles [47].

6. Conclusion

It is known that any secondary task is distracting [4]. But it is also known, that drivers engage into them nonetheless [11, 13, 14, 15, 16], and therefore use compensatory strategies to reduce distraction [56]. Hence should a system not only support but nudge this compensatory behaviour.

As the creativity workshop and the focus group revealed, spending the driving time usefully was the main motivational factor for drivers to engage in their smartphones while driving. Both the focus group and the online survey confirmed [18, 19, 20, 21] findings on the context-depending changes of driver's needs and requirements.

Supporting results of Naturalistic Driving Studies [11, 16] and the literature [26, 52, 53, 54, 55] context factors were found to have different effects on the willingness to engage in the secondary task in question. The results of the online survey have the potential to quantify driving situations defined by the street type, landscape, traffic density, weather and daytime.

In order to gain insights on opinions and perception of the behaviour [17], the cascade of the explorative approach, consisting of creativity workshops, a focus group and an online survey, provided a feasible way to obtain a comprehensive understanding of driver needs and requirements in extending infotainment features. For automotive manufacturers, designing an infotainment system that fulfils both the need for information and reduction of distraction is desirable.

6.1 Limitations

The limited sample size and heterogeneity regarding company affiliations for the creativity workshops and the focus group raise caution regarding interpretation and generalisation of the findings.

Nonetheless, the results of the online survey are only subjective perceptions. Therefore, it is needed to further evaluate these findings in a simulator study, where a control on driving situation factor levels is possible. The here identified utilities of the CBCA can then be tested as predicting factors. Regarding the CBCA, some participants noted to be missing the alternative of *"I would never use the function."*. The secondary task m*ake a shopping list* showed to be unsuitable, since supermarkets in Germany close at latest at midnight, so making a shopping list at night apparently did not make sense to participants.

6.2 Further Research

Further investigations on drivers' behavioural adaptations in using their mobile devices when driving a car should be pursued.

In order to test the interaction of driving situation and secondary task, a driving study is needed to investigate the effects on the Collision Avoidance Metrics Programme [48], that is driving, glance and event detection behaviour, plus on subjectively perceived distraction and disturbance. As compensatory behaviour while engaged in secondary tasks in different driving situations is explored, the contradiction of wanting to be connected without being distracted, can be resolved by designing adapting current infotainment systems accordingly.

In addition, a real-driving study over a longer timeframe is recommendable to outline driving scenarios and investigate the adaptation based on these.

As [29, 49] found, legislation influences the perceived risk and willingness to engage in secondary tasks on mobile devices while driving. Therefore, further investigations on the legislation of mobile device usage while driving are needed.

Due to adaptations of current guidelines of driver distraction [50] regarding portable mobile devices, a continuous research investigating subjective user needs and requirements shall be pursued.

7. References

7.1. Bibliography

[1] mm1: 'Digitalisierung im Auto: Sitzt die deutsche Automobilindustrie in Zukunft noch am Steuer?' Online on the Internet, 2015, URL: https://mm1.de/fileadmin/content/Whitepaper/mm1_White_Paper_Digitalisierung_im_Auto_9_2015.pdf (Accessed 28 April 2017)

[2] Walker, G. H., Stanton, N. A., & Young, M. S.: 'Where is computing driving cars?'. International Journal of Human-Computer Interaction, 2001, 13(2), pp. 203-229.

[3] Vollrath, M., & Krems, J.: 'Fahren', in: Vollrath, M., & Krems, J. F. (Eds.): 'Verkehrspsychologie. Ein Lehrbuch für Psychologen, Ingenieure und Informatiker.' (Kohlhammer, 2012, 1st edn.), pp. 26-40

[4] Wickens, C. D.: 'Multiple resources and performance prediction. 'Theoretical issues in ergonomics science, 2002, 3(2), pp. 159-177

[5] Fuller, R.: 'The task-capability interface model of the driving process.' Recherche – Transports - Sécurité, 2000, (66), pp. 47-57

[6] Summala, H., Lamble, D., Laakso, M.: 'Driving experience and perception of the lead car's braking when looking at in-car targets.' Accident Analysis and Prevention, 1998, 30 (4), pp. 401–407.

[7] Reimer, B.: 'Impact of cognitive task complexity on drivers' visual tunnelling.' Trans. Res. Rec.: J. Trans. Res. Board, 2009, 2138, pp. 13–19

[8] Tsimhoni, O., Smith, D., Green, P.: 'Address entry while driving: speech recognition versus a touch-screen keyboard.' Hum. Factors J. Hum. Factors Ergonomics Soc., 2004, 46 (4), pp. 600–610.

[9] Engström, J., Johansson, E., & Östlund, J.: 'Effects of visual and cognitive load in real and simulated motorway driving.' Transportation research part F: Traffic psychology and behaviour, 2005, 8(2), pp. 97-120.

[10] AAA Foundation for Traffic Safety: '2014 Traffic Safety Culture Index.' Online on the internet, 2015, URL: https://www.aaafoundation.org/sites/default/files/2014TSCIreport.pdf (Accessed 18 May 2017)

[11] Dingus, T. A., Klauer, S. G., Neale, V. L., et al.: 'The 100-car naturalistic driving study, Phase II-results of the 100-car field experiment (No. HS-810 593) '. National Highway Traffic Safety Administration, 2006

[12] World Health Organization: 'Mobile Phone Use: A Growing Problem of Driver Distraction.' WHO, 2011

[13] Dingus, T. A., Guo, F., Lee, S., et al.: 'Driver crash risk factors and prevalence evaluation using naturalistic driving data.' Proceedings of the National Academy of Sciences, 2016, 113(10), pp. 2636-2641

[14] Victor, T., Dozza, M., Bärgman, J., Boda, C. N., Engström, J., Flannagan, C., & Markkula, G.: 'Analysis of naturalistic driving study data: Safer glances, driver inattention, and crash risk.' SHRP 2 Report S2-S08A-RW-1, 2015

[15] Landau, A., Metz, B., Hargutt, V., et al.: 'Re-use of FOT data to assess the frequency and impact of distracted driving.' Presentation at the Naturalistic Driving Research Symposium, 2014, Blacksburg, Virginia, 26th of August 2014

[16] Carsten, O., Hibberd, D., Bärgman, J., Kovaceva, J., Pereira Cocron, M.S., Dotzauer, M. & Forcolin, F.: 'Driver Distraction and Inattention. UDRIVE Deliverable 43.1.'. EU FP7 Project UDRIVE Consortium, 2017

[17] Parnell, K. J., Stanton, N. A., & Plant, K. L.: 'What does current research tell us about why drivers engage with technological distractions: A Review.' 5th International Conference on Driver Distraction and Inattention, Paris, 2017

[18] Baltrunas, L., Kaminskas, M., Ludwig, B., et al.: 'InCarMusic: Context-aware music recommendations in a car.', in: Huemer, C. & Setzer, T. (Eds.) 'International Conference on Electronic Commerce and Web Technologies.', (Springer, 2011), pp. 89-100

[19] Dey, A. K.: 'Understanding and using context.' Personal and ubiquitous computing, 2001, 5(1), pp. 4-7

[20] Fischer, G.: 'Context-aware systems: the 'right' information, at the 'right' time, in the 'right' place, in the 'right' way, to the 'right' person.' Proceedings of the international working conference on advanced visual interfaces, 2012, pp. 287-294

[21] Helmholz, P.: 'Kontextorientierte Musikwiedergabe im Fahrzeug.', Doctoral dissertation, Technische Universität Braunschweig, 2015

[22] Parnell, K. J., Stanton, N. A., & Plant, K. L.: 'What technologies do people engage with while driving and why?.' Accident Analysis & Prevention, 2018, 111, pp. 222-237.

[23] Michalko, M.: 'Thinkertoys: A Handbook of Creative-Thinking Techniques' (Ten Speed Press, 2006, 2nd edn.)

[24] Krueger, R. A., & Casey, M. A.: 'Designing and conducting focus group interviews.' Social analysis, selected tools and techniques, 2002, 4(23), pp. 4-24

[25] Karrer, K., Glaser, C., Clemens, C., et al.: 'Technikaffinität erfassen–der Fragebogen TA-EG.' Der Mensch im Mittelpunkt technischer Systeme, 2009, (8), pp. 196-201

[26] Horberry, T., Anderson, J., Regan, M. A., Triggs, T. J. & Brown, J.: 'Driver distraction: The effects of concurrent in-vehicle tasks, road environment complexity and age on driving performance.' Accident Analysis and Prevention, 2006, 38, pp. 185-191

[27] Fastenmeier, W.: 'Autofahrer und Verkehrssituation. Neue Wege zur Bewertung von Sicherheit und Zuverlässigkeit moderner Strassenverkehrssysteme'. Mensch, Fahrzeug, Umwelt, Bd. 33. (Verlag TÜV Rheinland, 1995)

[28] Lerner, N., Singer, J. P., & Huey, R.: 'Driver strategies for engaging in distracting tasks using in-vehicle technologies (No. HS-DOT-810-919).' United States. National Highway Traffic Safety Administration, 2008

[29] Parnell, K. J., Stanton, N. A., & Plant, K. L.: 'Understanding drivers' strategies for engaging with in-vehicle technology while driving: An interview study' 5th International Conference on Driver Distraction and Inattention, Paris, 2017

[30] Taubman-Ben-Ari, O., Mikulincer, M., & Gillath, O.: 'The multidimensional driving style inventory - scale construct and validation.' Accident Analysis & Prevention, 2004, 36(3), pp. 323-332

[31] van Huysduynen, H. H., Terken, J., Martens, J. B., et al.: 'Measuring driving styles: a validation of the multidimensional driving style inventory.' Proceedings of the 7th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, 2015, pp. 257-264

[32] Addelman, S., & Kempthorne, O. (1961). 'Orthogonal main-effects plans.' Ames, Iowa State Universtity: Aeronautical Reserach Laboratory Office if Aerospace Research United States Air Force, 1996

[33] Rao, V. R.: 'Applied conjoint analysis.' (Springer, 2014)

[34] Stinson, D. R.: 'Combinatorial Designs.' (Springer, 2004)

[35] Backhaus, K., Erichson, B., & Weiber, R.: 'Fortgeschrittene multivariate Analysemethoden: eine anwendungsorientierte Einführung.' (Springer, 2015)

[36] Djokic, N., Salai, S., Kovac-Znidersic, R., Djokic, I., & Tomic, G.: 'The use of conjoint and cluster analysis for preference-based market segmentation.' Engineering Economics, 2013, 24(4), pp. 343-355.

[37] Spiessl, W., & Hussmann, H.: 'Assessing error recognition in automated driving'. IET Intelligent Transport Systems, 2010, 5(2), pp. 103-111

[38] DeSarbo, W. S., Ramaswamy, V., & Cohen, S. H.: 'Market segmentation with choice-based conjoint analysis.' Marketing Letters, 1995, 6(2), pp. 137-147.

[39] Huemer, A. K. & Vollrath, M.: 'Literature review on observational studies on cell phone use while driving' 5th International Conference on Driver Distraction and Inattention, Paris, 2017

[40] Lerner, N., & Boyd, S.: 'Task Report: On-Road Study of Willingness to Engage in Distraction Tasks (No. DOT HS 809 863)'. National Highway Traffic Safety Administration, 2005

[41] Lee, J. D.: 'Technology and teen drivers.' Journal of safety research, 2007, 38(2), pp. 203-213.

[42] Jung, T., Kaß, C., Schramm, T., & Zapf, D.: 'So what really is user experience? An experimental study of user needs and emotional responses as underlying constructs.' Ergonomics, 2017, 60(12), pp. 1601-1620.

[43] Brusilovsky, P.; & Millán, E.: 'User Models for Adaptive Hypermedia and Adaptive Educational Systems.' In: Brusilovsky, P., Kobsa, A. & Nejdl, W. (Eds.): The Adaptive Web, (Springer, 2017), pp. 3 – 53.

[44] Duarte, C. A.: 'Design and Evaluation of Adaptive Multimodal Systems', Doctoral Dissertation, Universidade de Lisboa, 2007

[45] Hastie, H. W., Johnston, M., & Ehlen, P.: 'Context-sensitive help for multimodal dialogue.' Proceedings of the Fourth IEEE International Conference on Multimodal Interfaces, 2002, pp. 93-98.

[46] Yerkes, R. M., & Dodson, J. D.: 'The relation of strength of stimulus to rapidity of habit-formation.' Journal of comparative neurology, 1908, 18(5), pp. 459-482.

[47] Farrell, P. S.: 'The hysteresis effect.' Human factors, 1999, 41(2), pp. 226-240.

[48] National Highway Traffic Safety Administration: 'Visual-manual NHTSA Driver Distraction Guidelines for In-vehicle Devices. Docket No. NHTSA-2010-0053', Washington, DC: National Highway Traffic Safety Administration (NHTSA), 2012

[49] Young, K. L., & Lenné, M. G.: 'Driver engagement in distracting activities and the strategies used to minimise risk.' Safety Science, 2010, 48(3), pp. 326-332.

[50] National Highway Traffic Safety Administration: 'Visual-Manual NHTSA Driver Distraction Guidelines for Portable and Aftermarket Electronic Devices. Docket No. NHTSA–2013–0137', Washington, DC: National Highway Traffic Safety Administration (NHTSA), 2014

[51] Oviedo-Trespalacios, O., Haque, M. M., King, M., & Washington, S.: 'Should I Text or Call Here? A Situation-Based Analysis of Drivers' Perceived Likelihood of Engaging in Mobile Phone Multitasking.' Risk Analysis, 2018, DOI: 10.1111/risa.13119

[52] Britschgi V, Penttinen M, Rämä P.: 'Finnish Drivers and the use of In-Vehicle Technologies- Comparison of the focus group study and the internet survey.' In: Pace J, Mendoza L. (Eds.): 'Proceedings of European Conference on Human Centred Design for Intelligent Transport Systems', (HUMANIST Publications, 2012)

[53] Ferreira A, Rôla S, Simões A, Piccinini G.: 'Perceptions of Portuguese Drivers about the Usage of Mobile Phone While Driving.' In: Pace J, Mendoza L. (Eds.): 'Proceedings of European Conference on Human Centred Design for Intelligent Transport Systems', (HUMANIST Publications, 2012)

[54] Hancox, G., Richardson, J., & Morris, A.: 'Drivers' willingness to engage with their mobile phone: the influence of phone function and road demand.' IET Intelligent Transport Systems, 2013, 7(2), pp. 215-222

[55] Young, K. L., & Lenné, M. G.: 'Driver engagement in distracting activities and the strategies used to minimise risk.' Safety Science, 2010, 48(3), pp. 326-332

[56] Young, R. A.: 'Cell Phone Conversation and Relative Crash Risk Update.' in: Khosrow-Pour, M. (Ed.): Encyclopedia of Information Science and Technology.' (IGI Global, 2018, 4th edn.), pp. 5992-6006

7.2. Pictures Fig. 4

[1] Stokpic, https://www.pexels.com/de/foto/stadt-strasse-strasse-italien-5166/, accessed 15 August 2017

[2] Chensiyuan, https://upload.wikimedia.org/wikipedia/commons/e/e7/Quebec_City_Rue_St-Louis_2010b.jpg, accessed 15 August 2017

[3] Nout Gons, https://www.pexels.com/photo/action-america-architecture-avenue-378570/, accessed 15 August 2017

[4] Negative Space, https://www.pexels.com/photo/road-clouds-mountain-car-34585/, accessed 15 August 2017

[5] Josh Sorenson, https://www.pexels.com/photo/landscape-hilly-hills-highway-59512/, accessed 15 August 2017

[6] Canon PowerShot Sx200 Is, http://maxpixel.freegreatpicture.com/Winter-Landscape-Brandenburg-Tree-Lined-Avenue-Road-1156383, accessed 15 August 2017

[7] **S**andor Bordas, https://de.wikipedia.org/wiki/Datei:04.12.2007._Pyhrn-Autobahn_-_A_-_panoramio.jpg, accessed 15 August 2017

[8] Klaus Foehl, https://upload.wikimedia.org/wikipedia/commons/8/80/Autobahn_Tauberbischofsheim01_2009-04-13.jpg, accessed 15 August 2017

[9] RolandSD, https://pixabay.com/de/road-polen-spur-autobahn-umzug-1667218/, accessed 15 August 2017

8. Appendices

Table 8. Fractional 3^4 Design [24], Plan 3 [19] for driving situations

PROFILE	FACTOR A street	B landscape	C traffic density	D weather	E day time
1	A1 city	B1 flat	C1 none	D1 dry	Day
2	A1 city	B2 hills	C2 moderate	D3 snow	Day
3	A1 city	B3 trees	C3 high	D2 rain	Day
4	A2 country	B1 flat	C2 moderate	D2 rain	Day
5	A2 country	B2 hills	C3 high	D1 dry	Day
6	A2 country	B3 trees	C1 none	D3 snow	Day
7	A3 highway	B1 flat	C3 high	D3 snow	Day
8	A3 highway	B2 hills	C1 none	D2 rain	Day
9	A3 highway	B3 trees	C2 moderate	D1 dry	day
10	A1 city	B1 flat	C1 none	D1 dry	night
11	A1 city	B2 hills	C2 moderate	D3 snow	night
12	A1 city	B3 trees	C3 high	D2 rain	night
13	A2 country	B1 flat	C2 moderate	D2 rain	night
14	A2 country	B2 hills	C3 high	D1 dry	night
15	A2 country	B3 trees	C1 none	D3 snow	night
16	A3 highway	B1 flat	C3 high	D3 snow	night
17	A3 highway	B2 hills	C1 none	D2 rain	night
18	A3 highway	B3 trees	C2 moderate	D1 dry	night

Table 9. Path-worth utilities for each secondary task

		Read a text message	Type a text message	Watch a video	Phone call hands-free	Make a shopping list	Adjust music volume
Street type	City	2.06	1.85	1.56	1.61	1.91	3.11
	Country	0.00	0.00	0.00	0.07	0.06	0.01
	Highway	0.89	1.29	0.75	0.27	0.74	1.62
Landscape	Flat	0.57	0.76	0.99	1.76	0.00	0.13
	Hills	0.00	0.49	0.00	0.01	2.10	0.00
	Trees	0.26	0.02	1.62	0.08	0.93	0.53
Traffic density	None	0.11	0.02	0.08	0.21	0.00	1.87
	Moderate	0.00	0.61	0.38	0.02	0.51	0.03
	High	0.96	0.29	0.88	0.55	2.21	2.63
Weather	Dry	0.00	0.14	0.28	0.00	1.23	0.00
	Rain	0.71	0.00	0.00	1.64	0.23	1.37
	Snow	1.20	1.34	1.76	1.33	0.80	3.48
Day time	Day	0.00	0.04	0.08	0.01	0.04	0.02
	Night	0.72	0.10	0.93	0.70	2.19	2.32