sciendo

DOI: 10.2478/ata-2022-0019

Acta Technologica Agriculturae 3
Nitra, Slovaca Universitas Agriculturae Nitriae, 2022, pp. 122–130

ASSESSMENT OF THE NEW DIGITAL SIDE MIRROR TECHNOLOGY FROM DRIVER'S SUBJECTIVE POINT OF VIEW CONSIDERING TRAFFIC SAFETY

Sudeep Sangamesh BABU[1], Jakub POVÝŠIL[1], Michal HRUŠKA[1]*, Petr VACULÍK[1], Petr BENDA[1], Anna Maria ZIFIA[2], Martin FŮS[3]

[1]Czech University of Life Sciences, Prague, Czech Republic
[2]Tilburg University, Tilburg, Netherlands
[3]Czech Technical University in Prague, Kladno, Czech Republic

The automotive industry is experiencing an era of technological innovations from conventional passenger cars, trucks to agricultural machinery. Digital side mirror technology is one of the latest topics in the field of advanced driver assistance systems which is developing rapidly. This study evaluates the applicability of digital side mirror technology in the car interior, based on drivers' feedbacks. The research was conducted in the form of a questionnaire to determine the drivers' reactions and affinity to new technology, based on personal experience gained in simulated traffic and also in real traffic situations. The data obtained from this research were then subjected to Pearson's Chi-squared test to evaluate the drivers' dependence and comfort with the digital side mirror technology. Subsequently, mainly statistically significant dependencies in the preferences of individual drivers were sought due to their personal and anthropometric parameters. The results published in this study can be used mainly to understand the process by which drivers form an opinion on new technology which may be key to their further stance on the technology and may also affect the commercial success of digital mirror technology during their involvement in serial production.

Keywords: car; automotive industry; assistance systems; angle of view; rear view

Since its advent, the automotive industry has undergone significant transformation both in the exterior and interior areas. The engines have become more efficient and reliable, the cockpit structures are more stable and additional features in the vehicle were added to ensure driver's safety. Until quite recently, the vehicle cockpit remained unchanged, since the priority had been given to driving activity (Regan et al., 2017). In the last decade, more importance was given to drivers' comfort and safety. Alongside these developments, there has been an increase in the research for the application of these new technologies and their effects on driving performance, efficiency and overall traffic safety (Häne et al., 2017; Polishchuk et al., 2021).

The applicability of the Digital Side Mirror (DSM) technology to ensure drivers' safety and increase the effectiveness of driving is the focus of this study, from the driver-centred perspective. Typical issues without a driver-centred design perspective include an overload of information, inadequate assistance to the driver, over-reliance on technology by drivers, negative behavioural adaptations to the technology and overall misuse of the new technology (Pampel et al., 2018; Regan et al., 2017; Viputsakul et al., 2020; Van Der Laan et al., 1997). It can be argued that the choice of vehicle is made based on the technology and its subsystems which would provide a sense of additional safety for the driver (Brookhuis et al., 2001; Lu et al., 2005). There are several categories of explanatory variables such as vehicle attributes, socio-demographic characteristics, age, gender, household characteristics, housing conditions, psychological motivation, etc., which determine the choice of a vehicle that are discussed in depth in several articles (Ferguson et al., 2018; Hackbarth and Madlener, 2018; Kim et al., 2006; Liao et al., 2017; Rahmani and Loureiro, 2019; Shinghal and Fowkes, 2002).

The DSM technology focuses on improving not only the aerodynamics of the vehicle but also the fuel-efficiency and noise reduction in the vehicle interiors (Park, 2017; Yong-Ju et al., 2018). The DSM technology is no longer used only in functional prototypes, but already in cars in series production. Lexus ES was the first series-produced car from Japan in 2018 which was equipped with the DSM technology with the DSM display placed in the area connecting the dashboard and the A-pillar trims (Capparella, 2018). The advantage of DSM displays is that they can be placed virtually anywhere in the vehicle cabin in the field of driver's vision (Beck et al., 2017; Häne et al., 2017; Large et al., 2016; Murata and Kohno, 2018). Summarized, these research articles state that if DSM displays are placed in the direct field of driver's vision, the reaction time to the critical situation and normal driving scenarios can be reduced. The different location of displays and the overall functionality of DSM technology need to be assessed for a comprehensive overview of the applicability of this technology in future commercial vehicles. There are other studies (Ayoub et al., 2021; Beck et al., 2021; Murata and Kohno, 2018; Pampel et al., 2020; Wittmann et al., 2006) carried out in the field of camera monitor system which our

Contact address: Michal Hruška, Czech University of Life Sciences, Prague, Kamýcká 129, 165 00 Praha Suchdol, Czech Republic, e-mail: jabko@tf.czu.cz

Table 1 Primary information on the participants concerning the measurements

Age		Place of residence		Dioptric glasses	
Up to 34	**35+**	**small town**	**regional city + Prague**	**Yes**	**No**
101	75	88	88	60	116

Table 2 Secondary information on the participants concerning the measurements

Level of education		Daily commuting to work		Number of driven km in total	
High school	**university**	**yes**	**no**	**up to 100 000**	**100 001+**
48	128	132	44	52	124

study corresponds to (similar to DSM technology) that state the on-road benefits and hands-on experience of the drivers with the technology.

One of the objectives of this research is to determine if there is a relationship between the measured parameters of the drivers (participants) and their preferences in the usability of DSM technology. The second objective is to verify if there is a dependency between the measured parameters of the drivers and their subjective sense of safety when using DSM technology in different driving scenarios. The final objective is to evaluate if there is a socio-demographic parameter dependency on the DSM technology acceptance. Through these objectives, this study reflects the hypothesis that there are dependencies of age, driving experience, etc., on the acceptance of new DSM technology. The research not only evaluates the usability of DSM technology, but also sets a baseline for future research and development.

Material and methods

Description of demographics

A homogeneous group of 176 participants took part in the field research. Parameters such as age, education, experience, etc., were collected from the participants for further statistical analysis. The age group of participants ranged from 21 to 54 years. Certain parameters that were set for the study participants included for the participant to have a valid driver's license for a passenger vehicle, required to have an unobstructed vision with the clear ability to orientate, without any other restrictions in the area of the musculoskeletal system or any other health complications that could skew the overall results. This was the first active experience with DSM technology for all test participants. The participants consisted of university and high school students and its employees due to organisational reasons. In addition to their age, the place of residence and more specific parameters related to personal driving experience are listed in Tables 1 and 2, each test subject also specified whether they commute daily to work or whether they use dioptric glasses to correct visual impairment. Due to the small percentage of women in the tested sample, the gender parameter was not included in the input data.

Description of location

A closed test polygon was selected for the field testing purposes where non-homologated vehicles can be operated. The dimensions of the test polygon allow a complete range of dynamic tasks to be performed, including simulation of actual operation up to a speed of 100 km·h^{-1}.

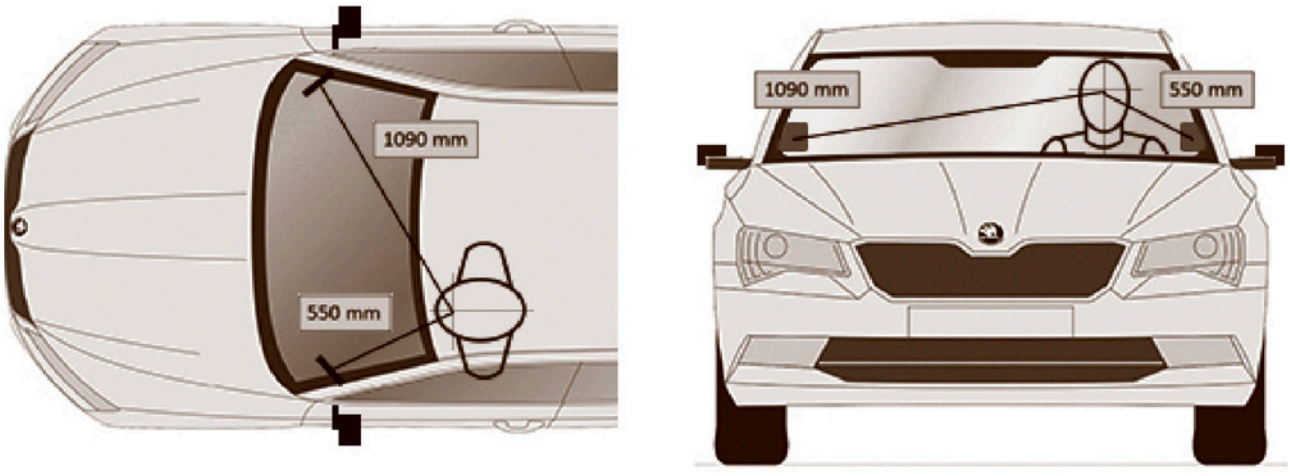


Fig. 1 Dimension to side mirrors from the centre of the head of 50 percentile human head
top view – left; front view – right

Table 3 Equipment description and specifications

Equipment	Description	Specification
Display	screen size	5.7"/14.5 cm
FeelWorld F570	resolution	1920 × 1080 p (16:9)
	brightness	460 cd·m^{-2} (LED)
	dimension	(5.8 × 3.2 × 0.7)"/(14.8 × 8.2 × 1.9) cm
Camera	resolution	4800 × 3200 p (3 : 2)
Sony DSC-RX0 II	sensor type	BSI – CMOS
	processor	BIONZ X
	focal length (equiv.)	24 mm
	maximum aperture	F4
	normal focus range	7.87"/20 cm

Description of equipment

Two identical Škoda Superb III test vehicles were used for testing. One of the vehicles was modified to remove both conventional side mirrors, which were replaced by digital side mirrors on both sides (Fig. 2). "Sony CyberShot Camera DSC-RX0 Mark II" (Sony, 2019) was used to capture the image, and the "FeelWorld monitor FW570" was used to display the image (Feelworld, 2017). The parameters of both elements are described in detail in Table 3. This particular camera was used in the experimental setup since the focal length of the camera was comparable to the human eye (Wang et al., 2021). To align with this particular model of camera, "FeelWorld monitor FW570" was used also for the high resolution it offers, which reduces pixelation in the image displayed. The connection between the sensing and display elements was secured with a cable. The location of displays has been selected to match the location of the conventional rear-view mirrors in the driver's field of vision. The hip-point (H-point) or seating reference point (SgRP or R-Point) position was used to verify the correct position for conventional side mirrors according to the standards given in the Federal Motor Vehicle Safety Standard (FMVSS) 111 (NHTSA, 2010) and the United Nations and Economic Commission of Europe (UNECE) regulation R46 and regulation R324 revision 4, also mentioned as ISO 16505 (ISO 16505, 2019) (United Nations, 2012). The distance to the right DSM display was 1090 mm, and the distance to the left DSM display was 550 mm measured from the centre of the head of the 50-percentile adult male dummy position (Fig. 1), which is considered the optimal seating position in the car (SAE J826, 2008). The position and angles of the DSM display were fixed in the vehicle and could not be changed by participants. The DSM displays were placed in an angle providing the same image, as they corresponded with the driver's axis of vision. Accompanying unmodified middle-class vehicles, in white colour, were used to simulate real driving scenarios.



Fig. 2 Setup of modified Škoda Superb III with DSM technology

Description of tasks and data collection

The tests, which enabled participants to gain personal experience with DSM technology, were divided into two main categories that included overtaking a proceeding car and parking (Fig. 3). The parking task was subdivided into two categories of transverse and parallel parking scenarios.

The overtaking and parking tasks were performed by participants in both test cars which were equipped with conventional side mirrors and DSM technology to compare the results and data for statistical analysis. Participants started the test alternately in one or the other vehicle to avoid influencing the data obtained from previous experience. It took each participant 30 minutes on average in each test vehicle to complete all test-related tasks. All tests were conducted outdoors in the month of September to maintain good lighting conditions for all participants. Data for the purposes of this study were obtained intentionally using structured questionnaires. This is a standard procedure for evaluating the usability and ergonomic level of the user interface (UIX) of the assessed technology (Sanchez, 1992), when it is necessary to obtain feedback from respondents. Hard data obtained during this testing will be published in separate papers. The data used for the research described in this work were performed by a standard User Experience (UX) testing method using questionnaire and experimental survey on a homogeneous group of participants.



Fig. 3 View from drivers' point of view from one of the driving tasks on the DSM display in the modified Škoda Superb III equipped with DSM technology

The questionnaire was divided into 2 main categories. The first category consisted of issues related to demographic information, and the second part concerned the personal opinions of the participants on tested DSM technology. The issues in this category included drivers' views on safety and confidence in the technology, ease of driving with the new technology and the estimated price they would be willing to pay for the technology if it was available as an option. For the purposes of this work, a total of 9 questions were used, the exact wording and percentage results are given in Table 4.

Upon completion of the measurement, all clinical data obtained were digitized and evaluated using contingency tables and Pearson's Chi-square analysis. Respondents had three possible answers for most questions, however, for three questions only dichotomous answers were used. These are the questions of price, display location and the requirement to include additional features in DSM technology.

Results and discussion

The results obtained during the measurements were statistically processed and evaluated using Pivot tables and Pearson's chi-squared test at a significance level of 0.05. As explained by McHugh (2013), "Pearson's Chi-square test" is a significance statistics which is a non-parametric (distribution free) tool designed to analyse group differences This non-parametric statistical method does not require equality of variances among the study groups

Table 4 Questions used for clinical data collection

Question	Description	Answers		
		option 1	option 2	option 3
A	What is the most accurate expression of the overall feeling for digital mirrors?	interesting	neutral	disappointment
		103 (59%)	60 (34%)	13 (7%)
B	Did the position of the display suit you?	yes	no	–
		104 (59%)	72 (41%)	–
C	How much are you willing to pay as an optional extra for DSM technology?	up to € 200	more than € 200	–
		104 (59%)	72 (41%)	–
D	Was the overall security of DSM technology sufficient?	safe	neutral	dangerous
		55 (31%)	86 (49%)	35 (20%)
E	Was it safe when parking?	safe	neutral	dangerous
		58 (33%)	98 (56%)	20 (11%)
F	Was it safe when overtaking?	safe	neutral	dangerous
		67 (38%)	90 (51%)	19 (11%)
G	Were you confident in the image? (Please write how much you trusted the digital image that the DSM displays provided)	I trust in the picture	I partially trust in the picture	I don´t trust in the picture
		96 (55%)	52 (29%)	28 (16%)
H	Did using DSM technology while driving make your day better?	rather yes	neutral	rather not
		32 (18%)	64 (36%)	80 (46%)
I	Would you appreciate more additional features in mirrors?	rather yes	rather not	–
		120 (68%)	56 (32%)	–

in the data. In hypothesis testing, P-value is the likelihood of getting test results that are at least as extreme as the results actually observed. A very small P-value means that such an extremely observed result would be very unlikely under the null hypothesis (Wasserstein and Lazar, 2016). Cramer's V is an intercorrelation between the variables. Cramer's V is represented as a value between 0 (zero) and 1 (one). The closer the value is to 1, the higher the correlation between the variables and vice versa (Acock and Stavig, 1979). The value of Cramer's V is used to state whether there is a relatively strong or weak association between the dependencies (Cramer, 1946). Furthermore, the adjusted residuals method was used for further refinement and better interpretation of the found dependencies. Table 5 shows the results with statistical parameters and with an evaluation of whether there was a statistical dependence on specific input data.

Based on the results presented in Table 5, it is clearly evident that there are several significant statistical dependences between the questions from the questionnaire and the data collected in Tables 1–2. From this qualitative research, dependencies between the drivers' opinions about the DSM technology can be understood, which is very important in the field of automotive innovations. Significant statistical dependencies were found for the questions related to position of DSM display (Question B) and ease of use (Question H) (Table 4). There was a high dependency found between the position of DSM display and place of participant's residence, since there is a higher probability of traffic density in larger cities and the need for frequent accommodation with recurrent changes in traffic conditions, while, in smaller cities, it is not necessary to use mirrors as often. However, it is evident from the analysis that the position of display caused certain difficulties for respondents who were diagnosed with an eye defect or used dioptric glasses. Other dependencies state that people who live in a larger city feel better about the researched technology overall when compared to people who live in smaller cities or villages. Older drivers felt more comfortable and willing to appreciate greater involvement of assistance systems even though they did not fully trust the technology and not considered it safe. On the other hand, young drivers were likely to appreciate in general vehicle parameters other than the quantity and technological level of assistance systems. As seen in the results, more people with higher education had the ability to appreciate the DSM technology. This can be explained by a greater degree of imagination in the field of available technologies, but also by the overall affinity of technically educated respondents. Significance was also seen in the data where the participants responded that using DSM technology would not make their driving any easier. This can be explained by the fact that the vehicle is an everyday tool for these respondents and thus merely a means of getting from home to work and back.

Other significant dependencies were found for the questions A, C, D and E (Table 4). Questions A, D and E are related to the feeling of safety while using the researched technology. Although 56% of the respondents felt neutral, 33% considered this technology safe compared to 11% who did not consider it safe. Drivers who commute to work every day are significantly experienced in traffic safety and considered this technology safe as well. However, it should be noted that large number of drivers who use dioptric glasses while driving did not consider this technology completely safe (Question G, Table 4). This dependency can be explained by the fact that during dynamic (overtaking) driving, the driver's head is usually static, and the driver does not have to increase or change the angle of reflection in the mirrors by moving the head as often as when parking. In this case, a DSM display that provides only a still image of the camera is not disqualified by this feature to the same extent as when parking. Most respondents who did not consider this technology safe were concerned about the image latency due to the nature of technology. The DSM technology used in the research had an image latency of about 0.3 seconds, which is quite comparable to the technologies used in series production vehicles. Reducing image latency and improving the visual parameters of the camera and display could lead to a possible improvement in driver's sense of security. It is also statistically confirmed that drivers with compensated eye defects have slightly lower confidence in the image provided by digital mirrors than participants without such impairments. This can be caused by the problematic process of eye accommodation when refocusing from a distance to close, which can cause some difficulties for drivers with compensated eye defects (Benjamin, 2006; Glasser, 2006). Participants generally were not willing to pay a high price for the DSM technology as a piece of additional equipment, which costs approx. € 200 on average. Based on the results, it was evident that younger drivers were willing to pay a larger price compared to older drivers (Table 1 and 4). Although no specific dependence on selected parameters could be demonstrated, it is evident that the vast majority of participants would appreciate more built-in features of the tested technology, such as overtaking vehicles, distance estimates, parking assistance graphics, etc. Considering the results, it is possible to conclude that acceptance of new technology depends not only on physical age, but also on cognitive age of the user (Hong et al., 2013). Hong et al. (2013) conducted experiments with participants, which were in the mid-age category 30 s to 40 s, who showed a different behaviour toward new technology that is similar to the observations presented. As seen in this study, there is a clear indication that drivers over the age of 35 have a higher degree of caution and distrust of such a revolutionary technology (dependencies can be seen in Tables 4–5). This may be explained by the generally lower confidence in modern technology and perhaps the higher degree of conservatism of older drivers (Hong et al., 2013).

Data collection and statistical processing were achieved with high quality, most of the data were verified as valid and the results can be used for further research or development of production solutions. Thanks to the participation of mostly technically educated experts in the field of automotive, the results can be given great importance. In addition to hard data (measurement of exact values), soft data (input and output questionnaires) were also collected. Participants thus had the opportunity to communicate their comments, suggestions, or ideas and point out the shortcomings of the tested technology.

Table 5 Dependency of questions from the questionnaire (questions A to I from Table 4) on driver parameters as specified in Table 1 and Table 2 evaluated using Pearson's chi-squared test

Questions		Place of residence	Age	Level of education	Daily commute to work	Dioptric glasses	Number of kms in total
A	χ^2	11.80	2.97	8.10	2.61	2.12	3.43
	critical value	3.84	3.84	3.84	3.84	3.84	3.84
	P-value	0.001	0.085	0.004	0.106	0.145	0.064
	cramer V	0.26	0.13	0.21	0.12	0.11	0.14
	dependence	confirmed	none	confirmed	none	none	none
B	χ^2	6.02	1.20	4.01	3.13	9.90	0.05
	critical value	3.84	3.84	3.84	3.84	3.84	3.84
	P-value	0.014	0.272	0.045	0.077	0.002	0.831
	cramer V	0.37	0.17	0.30	0.27	0.47	0.03
	dependence	confirmed	none	confirmed	none	confirmed	none
C	χ^2	0.38	5.45	0.56	0.13	0.54	6.12
	critical value	3.84	3.84	3.84	3.84	3.84	3.84
	P-value	0.540	0.020	0.453	0.723	0.462	0.013
	cramer V	0.09	0.35	0.11	0.05	0.11	0.37
	dependence	none	confirmed	none	none	none	confirmed
D	χ^2	0.35	3.10	7.53	2.67	3.91	1.35
	critical value	3.84	3.84	3.84	3.84	3.84	3.84
	P-value	0.554	0.078	0.006	0.102	0.048	0.245
	cramer V	0.04	0.13	0.21	0.12	0.15	0.09
	dependence	none	none	confirmed	none	confirmed	none
E	χ^2	2.62	0.21	0.16	8.80	3.08	7.12
	critical value	3.84	3.84	3.84	3.84	3.84	3.84
	P-value	0.105	0.643	0.693	0.003	0.079	0.008
	cramer V	0.12	0.03	0.03	0.22	0.13	0.20
	dependence	none	none	none	confirmed	none	confirmed

Continuation of the table 5

Questions		Place of residence	Age	Level of education	Daily commute to work	Dioptric glasses	Number of kms in total
F	χ^2	0.01	0.10	2.62	3.34	4.71	2.02
	critical value	3.84	3.84	3.84	3.84	3.84	3.84
	P-value	0.903	0.757	0.105	0.067	0.030	0.156
	cramer V	0.01	0.02	0.12	0.14	0.16	0.11
	dependence	none	none	none	none	confirmed	none
G	χ^2	1.36	1.16	0.01	1.42	3.97	1.59
	critical value	3.84	3.84	3.84	3.84	3.84	3.84
	P-value	0.244	0.281	0.944	0.233	0.046	0.207
	cramer V	0.09	0.08	0.01	0.09	0.15	0.10
	dependence	none	none	none	none	confirmed	none
H	χ^2	0.00	15.52	5.86	2.67	3.83	3.90
	critical value	3.84	3.84	3.84	3.84	3.84	3.84
	P-value	1.000	0.000	0.015	0.102	0.500	0.048
	cramer V	0.00	0.30	0.18	0.12	0.15	0.15
	dependence	none	confirmed	confirmed	none	none	confirmed
I	χ^2	1.68	0.00	10.06	0.56	0.10	1.50
	critical value	3.84	3.84	3.84	3.84	3.84	3.84
	P-value	0.195	0.964	0.002	0.455	0.756	0.220
	cramer V	0.10	0.00	0.24	0.06	0.02	0.09
	dependence	none	none	confirmed	none	none	none

Conclusion

The main scientific contribution of this work lies in understanding, assessment of direct reactions and feedback from drivers based on their personal experience with the tested DSM technology. This data is crucial in the process of determining the usability of the given technology. They are also very important for assessing drivers' confidence in the technology, which has a direct impact on traffic safety. Although DSM technology is currently being used in certain types of cars and trucks, no studies have yet been published on the applicability of DSM. Therefore, the results presented in this work are very valuable and can serve as a basis for further research in this area. This study had the opportunity to obtain a large amount of valuable primary data from a relatively homogeneous group of participants, which may be statistically interesting in terms of possible comparisons with other statistics. By using contingency tables and method of adjusted residuals, it was observed that statistically significant dependencies can be found between the preferences of the interviewed drivers in the field of image display behind a moving vehicle and their anthropometric and sociological parameters.

The aim of the research was to find out the opinions of drivers on the described technology, based on personal experiences. From the results we can conclude how drivers form an opinion on new technology which consequently has an impact on the commercial success of DSM technology in the market. Despite the fact that the DSM technology is already used in production, no similar studies have been carried out regarding driver's perception and acceptance of the technology. The results obtained can thus be used universally, because the essence of the investigated technology will be similar for all types of vehicles. It can also be argued that, for a statistically significant group of participants, conventional mirrors are still the first choice. It is also noteworthy to mention that questions related to performance of DSM display in harsh weather conditions (such as rain, snowfall, frost, etc,.) and different lighting conditions were not a part of this research. In this research, the DSM technology – its useability, overall safety of the driver using this technology and if the drivers perceive this technology as safe was being investigated.

In this study, drivers' age and use of dioptric glasses played a significant role in the acceptance of DSM technology. Drivers using dioptric glasses may face issues such as glare on the DSM display, accommodation, visual fatigue caused due to re-focusing and other factors.

In general, accommodation dynamics and its amplitude (according to Duane's curve) physiologically decrease with increasing age. The DSM display should be viewed as an image at medium or near distances, where the involvement of the eye's accommodation mechanism in synergy with pupil constriction and eye convergence is necessary to create a sharp image on the retina. Assuming optimal distance correction at a constant distance from the closer mirror (550 mm), the visual system must make an effort of approx. 1.75 D (Dioptre) to focus the image and approx. 1 D for farther distances (1090 mm). Although the parameters are very individual, together with the latency of the camera image, they also result in delayed perception. Even a lower delay than usual can naturally result in a subjective and an objective reduction in the sense of security when using the DSM technology. Using prescription glasses generally limits the area of sharpness within the perceived field of view. Further limitation by the spectacle correction sides (arms of the glasses) plays a significant role in the physiological limitation of the field of view, especially in the temporal direction.

The statistical analysis in this study clearly indicates a dependency of age, driving experience etc., on the acceptance of the new DSM technology by drivers and its applicability in conventional vehicles. The results presented can serve as a basis for further research, which would help refine the aforementioned or serve for other research that addresses the issue of DSM technology. Furthermore, this research can be applied in the process of designing DSM systems, especially the display location in the car cabin, with a focus on ergonomics and the overall functionality of the technology in increasing the drivers' performance. The data and hypotheses presented in this work can serve as auxiliary factors in the process of car design concerning potential target groups of customers.

Acknowledgments

This study was supported by the Department of Technological Equipment of Building at the Faculty of Engineering, the Department of Information Technologies at the Faculty of Economics and Management, the Czech University of Life Sciences Prague (CULS). The research thanks all the participants and parties involved in setting up the experiment in Milovice and the support of the employees of Edag Engineering CZ, Škoda Auto and Valeo. This study, thanks to all the invaluable suggestions and opinions of all the involved stakeholders who provided the research with an insight into the drivers' state of mind and expectations for the future of automotive digitalization. This paper is supported by "University Grant Competition – UGC" as a part of the project "Improvement in Quality of the Internal Grant Scheme" at the Czech University of Life Sciences, under project number 62/2021 (CZ.02.2.69/0.0/0.0/19_073/0016944).

References

ACOCK, A. C. – STAVIG, G. R. 1979. A Measure of association for nonparametric statistics. In Social Forces, vol. 57, no. 4, pp. 1381–1386.

AYOUB, H. S. – HUSSEIN, W. M. – ELBASHAR, Y. H. 2021. Investigation of automotive digital mirrors ergonomics through laser shadowgraphy and driver's real-road test questionnaire. In Journal of Optics-India, vol. 50, pp. 95–108.

BECK, D. – JUNG, J. – PARK, W. 2021. Evaluating the effects of in-vehicle side-view display layout design on physical demands of driving. In Human Factors, vol. 63, no. 2, pp. 348–363.

BECK, D. – LEE, M. – PARK, W. 2017. A comparative evaluation of in-vehicle side view displays layouts in critical lane changing situation. In Ergonomics, vol. 60, no.12, pp. 1682–1691.

BENJAMIN, W. J. 2006. Borish's Clinical Refraction. Oxford : Butterworth-Heinemann, 1712 pp. ISBN 9780750675246.

BROOKHUIS, K. A. – DE WAARD, D. – JANSSEN, W. H. 2001. Behavioural impacts of advanced driver assistance systems – an overview. In European Journal of Transport and Infrastructure Research, vol. 1, no. 3, pp. 245–253.

CAPPARELLA, J. 2018. Lexus ES will be the first car to replace side mirrors with cameras. Car and driver. Available at: https://www.caranddriver.com/news/a23103910/lexus-es-side-mirror-camera-digital/

CRAMER, H. 1946. Mathematical Methods of Statistics (PMS-9). Princeton, New Jersey : Princeton University Press, 575 pp. ISBN 0691080046

EN ISO 16505: 2019. Ergonomic and performance aspects of Camera Monitor Systems — Requirements and test procedures.

FEELWORLD. 2017. FEELWORLD F570 5.7 Inch Small 4K HDMI on Camera field Monitor. Product catalogue. Available at: http://www.feelworld.cn/ShowInfo.aspx?id=519&py=

FERGUSON, M. – MOHAMED, M. – HIGGINS, C. D. – ABOTALEBI, E. – KANAROGLOU, P. 2018. How open are Canadian households to electric vehicles? A national latent class choice analysis with willingness-to-pay and metropolitan characterization. In Transportation Research Part D: Transport and Environment, vol. 58, pp. 208–224.

GLASSER, A. 2006. Surgical restoration of accommodation in presbyopia. In Current Opinion in Ophthalmology, vol. 17, no. 1, pp. 12–18.

HACKBARTH, A. – MADLENER, R. 2018. Combined vehicle type and fuel type choices of private households: an empirical analysis for Germany. FCN Working Paper no. 17/2018.

HÄNE, C. – HENG, L. – LEE, G. H. – FRAUNDORFER, F. – FURGALE, P. – SATTLER, T. – POLLEFEYS, M. 2017. 3D visual perception for self-driving cars using a multi-camera system: calibration, mapping, localization, and obstacle detection. In Image and Vision Computing, vol. 68, pp. 14–27.

HONG, S. J. – LUI, C. S. M. – HAHN, J. – MOON, J. Y. – KIM, T. G. 2013. How old are you really? Cognitive age in technology acceptance. In Decision Support Systems, vol. 56, pp. 122–130.

KIM, H. – LEE, J. – KIM, D. K. 2006. The impact of age and health on vehicle choices among elders. In Journal of Family and Economic Issues, vol. 27, no. 3, pp. 437–457.

LARGE, D. R. – CRUNDALL, E. – BURNETT, G. – HARVEY, C. – KONSTANTOPOULOS, P. 2016. Driving without wings: The effect of different digital mirror locations on the visual behaviour, performance and opinions of drivers. In Applied Ergonomics, vol. 55, pp. 138–148.

LIAO, F. – MOLIN, E. – AN WEE, B. 2017. Consumer preferences for electric vehicles: A literature review. In Transport Reviews, vol. 37, no. 3, pp. 252–275.

LU, M. – WEVERS, K. – VAN DER HEIJDEN, R. 2005. Technical feasibility of advanced driver assistance systems (ADAS) for road traffic safety. In Transportation Planning and Technology, vol. 28, no. 3, pp. 167–187.

MCHUGH, M. L. 2013. The Chi-square test of independence. In Biochemia Medica, vol. 23, no. 2, pp. 143–149.

MURATA, A. – KOHNO, Y. 2018. Effectiveness of replacement of automotive side mirrors by in-vehicle LCD-effect of location and size of LCD on safety and efficiency. In International Journal of Industrial Ergonomics, vol. 66, pp. 177–186.

NHTSA: 2010. 49 CFR Parts 571 and 585. Federal motor vehicle safety standard, 221 pp. Available at: https://www.nhtsa.gov/sites/nhtsa.gov/files/fmvss/Rear_Visibility_NPRM_12032010.pdf

PAMPEL, S. M. – NOFAL, T. – BURNETT, G. 2018. A preliminary simulator study to investigate the effects of digital mirror failures on driving and glance behaviour, situation awareness, criticality and trust. In Proceedings of 6th International Conference on Driver Distraction and Inattention, Gothenburg : SAFER, IFSTTAR & ARRB, pp. 1–6.

PAMPEL, S. M. – SOUTHEY, T. J. R. – BURNETT, G. 2020. Understanding the distraction and behavioural adaptations of drivers when experiencing failures of digital side mirrors. In IET Intelligent Transport Systems, vol. 14, no. 7, pp. 775–782.

PARK, H. 2017. A rear-view side mirror with exterior lens to improve field of view and aerodynamics of automobiles. In SAE Technical Paper, pp. 1–5.

RAHMANI, D. – LOUREIRO, M. L. 2019. Assessing drivers' preferences for hybrid electric vehicles (HEV) in Spain. In Research in Transportation Economics, vol. 73, pp. 89–97.

POLISHCHUK, Y. V. – ASTAFYEV, V. L. – DEREPASKIN, A. I. – KOSTYUCHENKOV, N.V – LAPTEV, N. V. – KOMAROV, A. P. 2021. Impacts of automatic and parallel driving systems on the productivity of machine-tractor units in the Northern region of the Republic of Kazakhstan. In Acta Technologica Agriculturae, vol. 24, no. 3, pp. 143–149.

REGAN, M. A. – HORBERRY, T. – STEVENS, A. 2017. Driver acceptance of new technology: Theory, measurement and optimisation. Farnham Surrey, Burlington, Vt : Ashgate Publishing Company, 384 pp. ISBN 9781138077034.

SAE J826: 2008. Devices for use in defining and measuring vehicle seating accommodation – SAE International.

SANCHEZ, M. E. 1992. Effects of questionnaire design on the quality of survey data. In Public Opinion Quarterly, vol. 56, no. 2, pp. 206.

SHINGHAL, N. – FOWKES, T. 2002. Freight mode choice and adaptive stated preferences. In Transportation Research Part E: Logistics and Transportation Review, vol. 38, no. 5, pp. 367–378.

SONY. 2019. RX0 II premium tiny tough camera | DSC-RX0M2 | Sony US. Product catalogue. Available at: https://www.sony.cz/electronics/kompaktni-fotoaparaty-cyber-shot/dsc-rx0m2

UNITED NATIONS. 2012. Un Ece 12. Department of Transportation: October, pp. 1–43.

VAN DER LAAN, J. D. – HEINO, A. – DE WAARD, D. 1997. A simple procedure for the assessment of acceptance of advanced transport telematics. In Transportation Research Part C: Emerging Technologies, vol. 5, no. 1, pp. 1–10.

VIPUTSAKUL, S. – LARGE, D. R. – BURNETT, G. 2020. Enhancing drivers' awareness of passing pedestrians with exocentric digital mirrors. In Contemporary Ergonomics & Human Factors, pp. 1–4.

WANG, Y. – LI, P. – GUPTA, U. – OUYANG, J. – ZHU, J. 2021. Tunable soft lens of large focal length change. In Soft Robotics. Epub ahead of print. PMID: 34388046.

WASSERSTEIN, R. L. – LAZAR, N. A. 2016. The ASA statement on p-values: context, process, and purpose. In The American Statistician, vol. 70, no. 2, pp. 129–133.

WITTMANN, M. – KISS, M. – GUGG, P. – STEFFEN, A. – FINK, M. – PÖPPEL, E. –KAMIYA, H. 2006. Effects of display position of a visual in-vehicle task on simulated driving. In Applied Ergonomics, vol. 37, no. 2, pp. 187–199.

YONG-JU, C. – YONG-SANG, S. – SEUNG-YOP, L. 2018. Aerodynamic analysis and noise-reducing design of an outside rear view mirror. In Applied Sciences, vol. 8, no. 4, pp. 519.