# Safety4Bikes: Assistance Systems for Cycling Children to Increase Safety

R. Kappes[1], S. Fudickar[1], J. Deiters1, A. Matviienko[2], J. Heinovski[3], M. Franke[3], F. Klingler[3], C. Sommer[3],

F. Dressler[3], A. Johnson[4], W. Funk[4], C. Kraetsch[4], L. Brink-Abeler[5], M. Isken[1], S. Boll[2], W. Heuten[2], A. Hein[1]

[1]Carl von Ossietzky University of Oldenburg
Ammerländer Heerstr. 140, 26129, Oldenburg
{raphael.kappes1, sebastian.fudickar, jule.deiters, melvin.isken, , andreas.hein}@uol.de

[3]Heinz Nixdorf Institute and Dept. of Computer Science
Fürstenallee 11 , 33102 Paderborn
{heinovski, mario.franke, klingler, sommer, dressler}@ccs-labs.org

[5]GeoMobile
Emil-Figge-Straße 80, 44227 Dortmund
l.brinkabeler@geomobile.de

[2]OFFIS - Institute for Information Technology
Escherweg 2, 26121, Oldenburg
{andrii.matviienko, wilko.heuten, susanne.boll}@offis.de

[4]IfeS-Institute for empirical Sociology
Marienstraße 2, 90402, Nürnberg
{annika.johnsen, walter.h.funk, clemens.kraetsch}@ifes.uni-erlangen.de

**ABSTRACT**

Cycling is a popular urban mobility solution. However, cyclists are more vulnerable and relatively unprotected compared to other road users. In Germany, the number of accidents with cycling children increases dramatically between the ages of 8 and 14 years, which is caused by their not fully developed cycling skills and understanding of traffic. The project Safety4Bikes aims at mitigating the risk of young cyclists by developing appropriate modular assistance systems that detect situational hazards and promote safe behaviour. Within the project, we are developing novel visual, tactile and acoustic signals integrated in bicycles and helmets to convey information for children in an understandable and non-distracting way. Embedding the cyclist into the surrounding context, we develop and investigate sensor technologies, algorithms and routing strategies needed for identification of the behaviour of cyclists on the road, traffic signs, safest routes and trajectory corrections. Additionally, we focus on the enhancements of Car2X communication to enable the exchange of information with other vehicles. The project follows a user centric approach in which the developed system components are continuously tested and adapted to the needs and characteristics of the target group. Answering the question of how the components will have to interact with the user is an important part of the research. Therefore, we evaluate the efficacy of the

designed interaction and recognition methods as well as sensors, algorithms and routing strategies through laboratory experiments and bicycle simulators. With controlled test-track experiments on a test route, the components are further evaluated and optimised.

**Keywords:** Assistance System, Bicycle simulator, Road safety, Connected vehicles.

## 1 INTRODUCTION

Bicycles are a more environmentally friendly and healthier alternative to other means of transport and especially cars (Johansson et al., 2017) and they are also very important in the field of urban transportation (Adams et al., 2017). Another advantage over cars is that not only adults are able and allowed to use them: Children start riding bicycles in early childhood and for children from about ten years of age, i.e. from lower secondary school onwards, not only the distances covered by bicycles increase, but also their independence from their parents. During this time, the bicycle plays an important role in independent mobility and movement (Funk, 2010). However, cycling children are among the more vulnerable road users: On the one hand, they are not fully developed yet with regard to their physical-motoric, social and cognitive skills (Johnsen and Funk 2017; Schmidt and Funk, 2019) and on the other hand, they are relatively unprotected in road traffic compared to car occupants. E.g. the official German traffic accident statistics show that the number of accidents rises rapidly between the ages of 10 and 15 (Figure 1). These accidents are often caused by misconduct in road traffic, e.g. wrong use of the road, incorrect behaviour when turning off or failure to observe right-of-way regulations (Destatis, 2017).In the context of the project Safety4Bikes, a modular assistance system for cyclists and particularly cycling

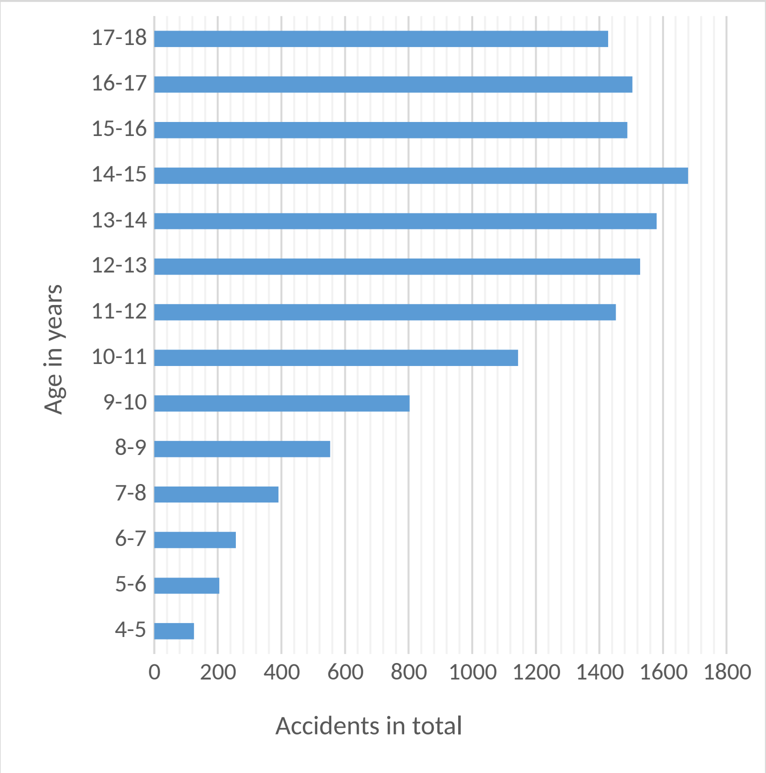


*Figure 1: Bicycle accidents of children and adolescents in 2017 in Germany (Destatis, 2017).*

children is developed which observes the user’s traffic behaviour and draws attention to the correct behaviour in certain situations, sends warnings or notifications in the case of acute dangers in the immediate vicinity and avoids potentially dangerous situations by adapting the driving route according to the current traffic. Therefore, these critical situations need to be determined, suitable sensors need to be developed and bicycles need to be integrated into Car2X communication - that is, the wireless network that connects future vehicles on the road (Sommer and Dressler, 2014). Also, the implemented educational measures, like feedback on the ride, should be effective and child-friendly. The aim is to prevent bicycle accidents from rising continuously during the years of early adolescence. S

afety for cycling children can be enhanced by educational measures, traffic infrastructure improvements and system enhancements, for which some preparatory work already exists: Behavioural prevention and educational measures such as driving-training reduce the risk of accidents significantly, especially at a young age (Ducheyne et al., 2014). However, these measures reach biological and developmental psychological limits in children. In the area of traffic infrastructure, in addition to the establishment of special cycle paths, additional adaptations such as in the Traffic Eye Zurich, where a context-sensitive, premature release of traffic lights for cyclists is enabled (Jordova et al., 2012) were confirmed to be beneficial.

Technical adaptations of the bicycle primarily increase the visibility and attention guidance of cyclists: The LucidBrake is an intelligent brake light that simultaneously increases visibility and indicates future driving manoeuvres to other road users at an early stage (Santiago-Saavedra and Mercado-Castellanos, 2018). Grosse-Puppendahl et al. (2015) present so-called wearable low-resolution displays, which are attached to the cyclist's body or clothing increasing the cyclist's visibility and enabling the display of abstract information.

Another approach is equipping the bicycle with sensors enhancing security: In a presentation by Volvo, POC and Ericsson at CES2015 a concept was shown which warns cyclists of approaching cars at unclear intersections by means of LEDs illuminated in the field of vision (Ruß and Naumann, 2015).

Should an accident nevertheless occur, the Connected Bike can notify the emergency doctor and thus accelerate the arrival of the first responders if necessary (Adams et al., 2017). In the field of route planning and assessment, smartphone applications and internet services for cyclists can increase road safety. For instance, the website RideTheCity excludes dangerous road areas during route planning and chooses safe routes with bicycle paths (Hübner et al., 2017). Not only adaptations to bicycles are taken into consideration: Technical adaptations of cars can improve the perception of cyclists by road users and therefore enhance the safety of cyclists. The focus is on improved attention guidance for the driver. The Bike Sense Concept integrates interactive elements on the vehicle body that can warn motorists about cyclists in their vicinity (Biondi and Skrypchuk, 2016). Ganzhorn et al. (2011) suggest warning of children at school bus stops by highlighting these areas in navigation systems. The LEXGUARD system informs automobile road users as soon as other road users are in the blind spot (De Lausnay et al., 2011). The project Active Pedestrian Safety (AFUSS) also tries to identify these blind-spot-situations by means of sensors mounted on the vehicle (Kranz et al., 2016). The Car2X solution prevents accidents between two cars by equipping vehicles with communication systems that send status messages at regular intervals with notes on risk situations such as traffic jams (Kleine-Besten et al., 2012). A considerable amount of research on Car2X is now derived from computer simulations which, however, only take cars into account (Mühlbacher et al. 2011). However, with the current advancement for improving bicycle safety, conceivable demand still remain regarding the applicability for children: Neither environmental sensors nor interaction methods suitable for children have been developed for bicycles yet. This, however, is very important because young adolescents are a particular risk group for bicycle accidents (Figure 1). As their cognitive and motor skills differ from those of adults (Johnsen and Funk 2017; Schmidt and Funk, 2019), systems developed for adults cannot be transferred to children without further work. Technical approaches could be especially suitable for children because they could compensate developmental constraints and sensory limitations with sensors and smart prediction. Another aspect to be considered is dynamically adapting the driving route depending on the current safety situation on the street and suggesting safer routes. By this approach, detours have only to be chosen if there is a safety issue on the normal route and thus the acceptance of these detours could be higher than of statically defined ones. Notable is also that the urgently needed integration of cyclists into the Car2X system has not been taken into account in the standards yet. It is important to analyse to what extent and with what adaptations the computer simulations and the respective communication protocols established today can be transferred to cyclists. Through this, the motorists’ attention can be drawn to cyclists and accidents can be prevented when obstacles impair the view of road users. However, not only motorists but also cyclists need to be warned so they can react appropriately. Using the already existing Car2X platform is advantageous, as cars would not need completely new equipment for this. Educational measures also reduce the risk of accidents (Ducheyne et al., 2014), so these should not be disregarded. While bicycle training and road safety education is already established in almost all German schools (Funk, 2010), in-situ education is not implemented, yet. This, however, would increase the effectivity because the repetition and automation of actions as well as the transfer of knowledge to other situations improve the sustainability of what has been learned (Edelmann and Wittmann, 2012). In consequence, this article introduces a corresponding system components and their inter-play within a cycling system especially targeting children.

## 2 RESULTING SYSTEM TO INCREASE SAFETY

To combine all of the aforementioned requirements and thus profit from all of them simultaneously, it is necessary to develop an assistance system for bicycles with various components: The assistance system to be developed is a combination of software and hardware components consisting of sensors, actuators and processors on the bicycle and the helmet seen in Figure 2. Methods for environmental and behavioural recognition are implemented which make it possible to recognize dangerous situations. Multimodal and ambient human-technology interactions for the bicycle and the helmet provide especially cycling children with information about routes and reminders of certain actions, as well as warnings of acute dangers without distracting from traffic. As user interface a smartphone application is chosen as, in Germany, smartphones are widespread even among young adolescents (Berg, 2017). Children and persons responsible for traffic education, such as teachers and traffic guards, contribute to the

*Figure 2: The implemented bicycle in the scope of our project.*

development of the assistance system with their practical experience and their proximity to the target group.

To meet the needs of the target group and identify the corresponding requirements for the assistance system the cognitive and motor abilities of children during cycling manouvers are investigated. To this end, established models of developmental psychology are considered and possible improvements to be offered by assistance systems  are extracted. Also, the analysis of childrens’ psychomotor and cognitive skills contributes to understand why especially children get distracted from the traffic and how to overcome this. Another point of interest is for which purposes children use their bicycles, as these data are not collected in the official statistics but can be correlated with target group-specific accident causes. Therefore, understanding why children use their bicycles can provide indications of approaches to accident prevention, e.g. in which cases an assistance system could help.

Additionally, the cognitive abilities of children need to be taken into consideration so the operation of the assistance system does not overstrain or distract the users.

In addition, focus group discussions with parents and children are initiated to assess the attitudes of both towards technical assistance systems on bicycles. It is necessary to identify if technical solutions are trusted and which level of assistance is tolerated by the target group. This leads to ethical, social and legal aspects, for instance, research with and on minors, the intervention of technical systems in the autonomy of action or possible social monitoring by parents. These aspects need to be identified and an adequate handling should be elaborated.

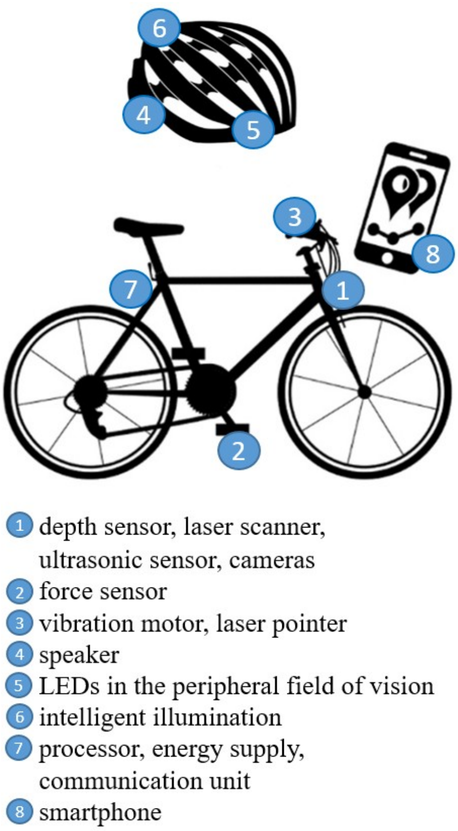


*Figure 3: Components of the assistance system.*

**2.1 Components for assistance**

The components of the assistance system are divided into sensors, actuators, processors and a smartphone application (Figure 3). Sensors are, for example, depth sensors, laser scanners and ultrasonic sensors on the handlebar. Additionally, cameras in driving direction and directed to the cyclist or force sensors on the pedals are implemented. Actuators are vibration motors on the handlebar, helmet-mounted speakers and LEDs in the peripheral field of vision or glasses with integrated displays. The processors, the communication unit and the rechargeable battery are located at the bicycle's back end. As the smartphone with the application is not meant to be used while cycling, it does not need to be attached to the bicycle.

### 2.2 Detection of Acute Dangerous Situations

The bicycle and helmet are equipped with suitable sensors and communication technology. Depth cameras are used to record the surroundings, the other road users and cyclist itself and providing spatial information of them. The covered areas by the depth cameras are showed in Figure 4. With force sensors and inertial measurement units (IMUs) in the pedals we determine the revolutions per minute by the cyclist and if the cyclists stands or sits. Further the orientations of the feet are important to measure the power and to observe barking maneuvers by an existing backpedal brake system. Additional IMUs and odometry provide insights on the movement and speed of the bicycle and extend GPS-based positioning information of the cycle. The imaging system is used to recognise the traffic situation and the user's traffic behaviour such as viewing direction and hand signals and is essential part for identifying cyclists' recognition of dangerous situations.

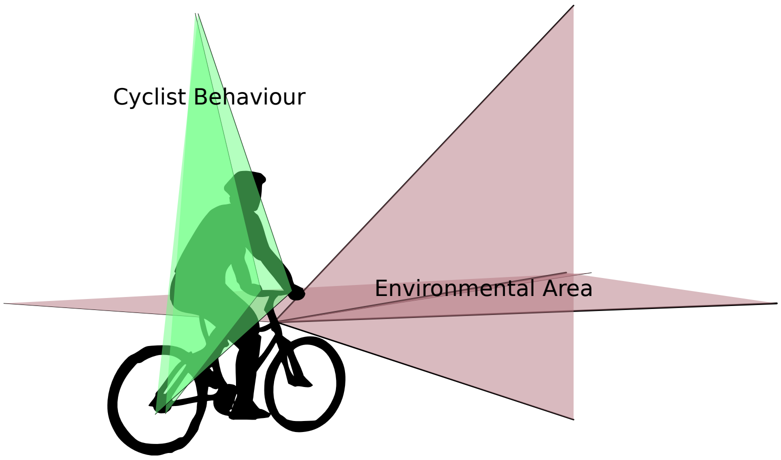

*Figure 4: Areas of the imaging system.*

A suitable position for sensors on bicycles and helmets does not impair the safety and the users' comfort and convenience. At the same time, the sensor positioning considers sensors' optimal recognition of surrounding and the cyclist. Therefore, a thorough analysis of the sensors and the design space is necessary and the suitability of sensors is evaluated in terms of accuracy and suitability so an ideal sensor-setup can be identified.

In addition, existing libraries such as OpenPose for posture tracking of the cyclists (Zhe et al., 2017) and KittiBox for car-detection (Teichmann et al., 2018) are integrated (examplistic shown results shown in Figure

5). Based on this extracted fundamental information, classification algorithms that distinguish critical from non-critical situations and compliant from non-compliant behaviours have still to be implemented.

Increasing the information density, these algorithms will consider addition information obtained by the sensors, radio communication between bicycles and cars via Car2X. In consequence, computer traffic simulations are extended to bicycles (Heinovski et al., 2019) and a protocol that enables the communication of bicycles via Car2X is derived, so that bicycles can be included in the already existing wireless network between future vehicles without the need to change existing standards (Loewen et al., 2017).

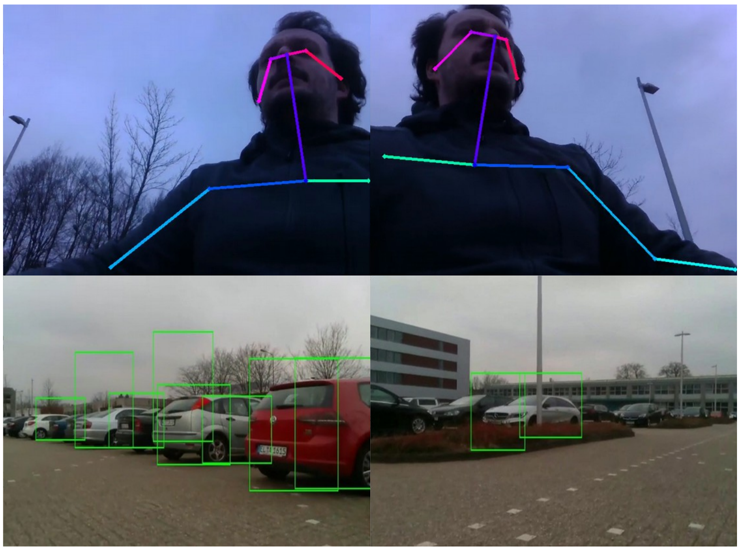

*Figure 5: Environmental and cyclist posture detection for behaviour classification.*

**2.3 Smartphone Application as User Interface and Route Planner**

A smartphone application is used as a platform connecting all components of the assistance system. The main purposes of this app are navigation control, an overview of the current situation on the route and instructions concerning traffic behaviour. The app should only be operated before and after the ride, but not while cycling.

The design for the application is suitable for children. Therefore, their requirements for the app and their ability to operate it are taken into consideration and different prototypes are iteratively evaluated and further developed by the target group.

Since the app informs the user when a misconduct they committed is detected, it is evaluated how this educational measure can be presented in an encouraging and understandable way.

In addition to the educational aspects, the system contains a routing algorithm for bicycle paths and reacts dynamically to current dangerous situations on the route. The corresponding routing algorithm dynamically identifies the currently safest routes. For this, separated bicycle paths and other bicycle-related infrastructure are included into a map. Furthermore, the determination of critical sections of the route in almost real time is realised by using the sensor data of other bicycles equipped with the assistance system on this route. To this end, the users of the assistance system are connected among each other via mobile communication. It is defined which situations should be classified as dangerous, in which cases detours are the better option and maximal suitable route-distance extensions resulting from detours without challenging the user's acceptance. For classifying dangerous situations, accident statistics give indications of potentially dangerous traffic situations.

## 2.4 Communication of Instructions and Hazard Warnings

Through a series of laboratory and controlled test-track experiments, multimodal assistance systems to encode warnings and navigation cues and traffic behavior recommendations have been investigated. We investigated especially visual cues integrated in the helmets and on the handlebar, acoustic signals and speech in the helmet, and vibrotactile feedback on the grips of the handlebar.

### 2.4.1Warnings

In our experiments we distinguish between two types of warning signals: directional cues and immediate actions (Matviienko et al., 2018). Directional cues are used for guiding cyclists' attention and immediate actions imply a breaking after perceiving an alert. In our work [29], we showed that with the support of warnings child cyclists faced no accidents in the bicycle simulator. Additionally, we discovered that children spend more time perceiving visual than auditory or vibrotactile cues. We also found that unimodal encodings were applicable for directional cues and multimodal for immediate actions. Lastly, trimodal warnings performed better for understandability and lead to shorter reaction times.

### 2.4.2 Navigation cues

In the experiments for the navigational cues, we found that auditory navigational cues were the most understandable and the least prone to navigation errors, and the vibration feedback coupled with the speech navigation instructions might be used as a reminder to show hand signals before performing a turn (Matviienko et al., 2019).

## 3 CONCLUSION

Considering the recent state of the art regarding bicycle safety, potential can be especially seen in enhanced technical systems for cyclists. The aim of Safety4Bikes is the development of an assistance system that is connected with a smartphone application. A human-centred design process ensures that the individual modules take the needs and requirements of the target group into account.

To this end, the cognitive and motor skills of children will be evaluated and a concept for instructions for cyclists will be developed. Above that, suitable sensors and measuring points for bicycles will be identified and existing Car2X communication will be extended to bicycles. Additionally, changing routes dynamically depending on the current safety situation will be made possible. The developed driver assistance system will be evaluated by children on a demonstrator in a protective environment. Still, the efficacy of the whole system needs to be evaluated and is part of our future work as well as the completion by a cyclist behaviour model.

**Acknowledgments**

Research reported in this paper was conducted in the context of project

Safety4Bikes, supported by the German Federal Ministry of Education and

Research (BMBF) under award number 16SV7668.

**REFERENCES**

Adams, V., Murari, S. and Round, C., 2017. “Biking and the Connected Bike”. In *Disrupting Mobility. Impacts of Sharing Economy and Innovative Transport on Cities*. Springer, 310. doi: 10.1007/978-3-319-51602-8

Andrii Matviienko, Swamy Ananthanarayan, Shadan Sadeghian Borojeni, Yannick Feld, Wilko Heuten, and Susanne Boll. 2018.Augmenting bicycles and helmets with multimodal warnings for children. In Proceedings of the 20th International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI '18). ACM, New York, NY, USA, Article 15, 13 pages. DOI: https://doi.org/10.1145/3229434.3229479.

Andrii Matviienko, Swamy Ananthanarayan, Abdallah El Ali, Wilko Heuten, and Susanne Boll. 2019. NaviBike: Comparing Unimodal Navigation Cues for Child Cyclists. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (CHI '19). ACM, New York, NY, USA, Paper 620, 12 pages. DOI: https://doi.org/10.1145/3290605.3300850.

Alrutz, D. 2016. “Influences of the increasing use of pedelecs on traffic safety and special demands to cycling facilities”. In *Straßenverkehrstechnik 60*. KIRSCHBAUM VERLAG, 409-416. ISSN: 0039-2219

Berg, A. 2017. “Mehrheit hat mit 10 Jahren eigenes Smartphone”. In *Kinder und Jugend in der digitalen Welt*. Bitkom. Url: https://www.bitkom-research.de/WebRoot/Store19/Shops/63742557/591A/BCF4/73A6/4749/7F68/C0A8/2ABB/D60E/170512_Bitkom_PK_Kinder_und_Jugend_2017.pdf

Biondi, F., Skrypchuk, L. 2016. “Use Your Brain (and Light) for Innovative Human-Machine Interfaces”. In *Advances in Human Factors and System Interactions*. Springer, 101-102.. ISBN: 978-3-319-41956-5

De Lausnay, S., Standaert, T., Stevens, N., Joseph, W., Verloock, L., Goeminne, F. and Martens, L. 2011. “Zigbee as Means to Reduce the Number of Blind Spot Incidents of a Tuck”. In *2011 IEEE 22nd International Symposium on Personal, Indoor and mobile Radio Communications. doi: 10.1109/PIMRC.2011.6139698*

Ducheyne, F., De Bourdeaudhuij, I., Lenoir, M., and Cardon, G., *2014*. “Effects of a cycle training course on children’s cycling skills and levels of cycling to school”. In *ACCIDENT ANALYSIS AND PREVENTION*, *67*, 49–60. doi: 10.1016/j.aap.2014.01.023

Edelmann, W., Wittmann, S., 2012. “Lernpsychologie”. Beltz. ISBN: 978-3621277037

Funk, W. 2010. “Kinder als Radfahrer in der Altersstufe der Sekundarstufe I”. In *Deutscher Verkehrssicherheitsrat (ed.): Risiko raus. Fachliche Beiträge zu Themen der Kampagne*. Verkehrssicherheit, 14. Deutscher Verkehrssicherheitsrat, 39-71. ISSN: 1618-6540

Ganzhorn, M., Diederichs, J. P. F. and Widlroither, H., *2011*. “Enhancing the reproduction of road signs in automotive HMIs to protect children”. In *ITS Telecommunications (ITST)*, *2011 11th International Conference*, 338-344. ISBN: 978-1-61284-670-5

Grosse-Puppendahl, T., Bechthold, O., Strassel, L., Jakob, D., Braun, A. and Kuijper, A. “Enhancing Traffic Safety with Wearable Low-Resolution Displays”. In *iWOAR 2015 – 2nd international Workshop on Sensor-based Activity Recognition and Interaction*. ACM. ISBN: 978-1-4503-3454-9

Heinovski, J., Stratmann, L., Buse, D. S., Klingler, F., Franke, M., Oczko, M-C. H., Sommer, C., Scharlau, I., and Dressler, F., 2019. "Modeling Cycling Behavior to Improve Bicyclists' Safety at Intersections – A Networking Perspective," Proceedings of 20th IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM 2019), Washington, DC, June. (to appear).

Hübner, K., Schünemann, B., Schilling, T. and Radusch, I.,, 2015. “On assessing road safety aspects of a cycling router application”. In *2017 5th International Conference on ITS Telecommunication (ITST)*. IEEE. doi: 10.1109/ITST.2017.7972199

Johnsen, A., Funk, W. 2017. “Safety4Bikes. Arbeitspaket 1: Nutzerstudien. Analyse der Ziel- und Anspruchsgruppen. Bericht”. Nürnberg: Institut für empirische Soziologie an der Friedrich-Alexander-Universität Erlangen-Nürnberg.

Johansson, C., Lövenheim, B., Schantz, P., Wahlgreen, W., Almström, P., Markstedt, A., Strömgren, M., Forsberg, B., Sommar and J. N., 2017. “Impacts on air pollution and health by changing commuting from car to bicycle”. In *Science of the Total Environment 584-585*. Elsevier, 55-63. doi: https://doi.org/10.1016/j.scitotenv.2017.01.145

Jordova, R., Sperat, Z., Barta, D., Tripodi, A., Persia, L., De Jong, M., Jorna, R., van der Kloof, A. and Zoer, H. J., 2012. “Evaluation of selected applications for safe cycling regarding potential standardisation”. In *Recommendations on standardisation and a research agenda*, 13-18.

Kleine-Besten, T., Kersken, U., Pöchmüller, W. and Schepers, H., 2012. “Navigation und Telematik”. In *Handbuch Fahrerassistenzsysteme*. Springer, 599-624. doi: 10.1007/978-3-658-05734-3

Kranz, T., Hahn, S. and Zindler, K., 2016. “Nonlinear Lateral Vehicle Control in Combined Emergency Steering and Braking Maneuvers”. In *2016 IEEE Intelligent Vehicles Symposium (IV)*. IEEE, 603-610. doi: 10.1109/IVS.2016.7535449

Limbourg M., 2008. “Kinder unterwegs im Straßenverkehr. Prävention in NRW 12“, Unfallkasse Nordrhein-Westfalen, Düsseldorf. https://www.unfallkasse-nrw.de/fileadmin/server/download/praevention_in_nrw/praevention_nrw_12.pdf

Loewen, S., Klingler, F., Sommer, C., Dressler, F., 2017. "Backwards Compatible Extension of CAMs/DENMs for Improved Bike Safety on the Road", Proceedings of 9th IEEE Vehicular.

Maring, W.; Van Schagen, I. (1990). „Age dependence of attitudes and knowledge in cyclists“, Accident Analysis & Prevention, 22 (2) pp. 127-136. doi: https://doi.org/10.1016/0001-4575(90)90064-R

Mühlbacher, D., Maag, C., Krüger, H. P., 2011. “Die Pulksimulation als neue Methode zur Erfassung der Wirkung von Car2X-basierten Fahrerassistenzsystemen”. In *7. Workshop Fahrerassistenzsysteme.* FAS.

Ruß, T., Naumann, S., 2015. “Avoiding collisions between pedestrians/cyclists and vehicles at signal controlled intersections using V2X”. In *Research Gate*.

Santiago-Saavedra, E. J., Mercado-Castellanos, F. J., 2018. “DEBI (Device for Bikes)”. San Pedro Tlaquepaque, 3.

Schmidt, J.; Funk, W., 2019. “Stand der Wissenschaft. Kinder im Straßenverkehr. Forschungsprogramm Straßenverkehrssicherheit FE 82.0559/2012. Schlussbericht”. Nürnberg: Institut für empirische Soziologie an der Friedrich-Alexander-Universität Erlangen-Nürnberg.

Sommer, C. and Dressler, F., 2014. “Vehicular Networking“, Cambridge University Press.

Statistisches Bundesamt (Destatis), 2018, “Verkehrsunfälle. Kinderunfälle im Straßenverkehr. 2017“, Technical Report, German Federal Statistical Office, Wiesbaden. https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Verkehrsunfaelle/Publikationen/Downloads-Verkehrsunfaelle/unfaelle-kinder-5462405177004.pdf?__blob=publicationFile&v=4

Teichmann, M., Weber M., Zöllner M., Cipolla R., Urtasun R., "MultiNet: Real-time Joint Semantic Reasoning for Autonomous Driving," *2018 IEEE Intelligent Vehicles Symposium (IV)*, Changshu, 2018, pp. 1013-1020. doi: 10.1109/IVS.2018.8500504 .

Zhe C., Gines H., Tomas S., Shih-En Wei, Yaser Sheikh. 2017. “Realtime Multi-person 2D Pose Estimation Using Part Affinity Fields”, In 2017 IEEE Conference on Computer Vision and Pattern Recognition (CVPR), July, pp. 1302-1310. doi: 10.1109/CVPR.2017.143

Zeuwts, L., Vansteenkiste, P., Cardon, G., Lenoir, M. , 2016. “Development of cycling skills in 7-to 12-year-old children”, Traffic injury prevention 17 (7), pp. 736-742. doi: 10.1080/15389588.2016.1143553