🏆 *reviewed paper*

Road Safety from Cyclist's Perspective

Magdalena Schmidkunz, Olaf Schroth, Peter Zeile, Ulrich Kias

(B. Eng. Magdalena Schmidkunz, Weihenstephan-Triesdorf University of Applied Sciences, magdalena.schmidkunz@yahoo.de)
(Prof. Dr. Olaf Schroth, Weihenstephan-Triesdorf University of Applied Sciences, Department of Landscape Architecture, olaf.schroth@hswt.de)
(Dr.-Ing. Peter Zeile, Karlsruhe Institute of Technology, Faculty of Architecture, Institute of Urban and Landscape Design, peter.zeile@kit.edu)
(Prof. Dr. Ulrich Kias, Weihenstephan-Triesdorf University of Applied Sciences, Department of Landscape Architecture, ulrich.kias@hswt.de)

1 ABSTRACT

Road safety is an essential design requirement in planning processes of cycling infrastructure. An evaluation criterion for safety are accident statistics, but this criterion lacks reliability with regard to cycling accidents because many accidents are not documented. In addition, an exclusive view of accident statistics only is inadequate because road safety also includes aspects such as objective as well as subjective safety of cyclists. In order to consider the cyclist's perspective in the planning of cycling facilities, an exploratory study, based on the concept of the Urban Emotions Inititative, was carried out in Augsburg and presented in this contribution.

The aim of the study was to investigate the influence of cycling infrastructure on the cyclist's stress and the perception of safety. As a result, 1040 stress situations of 26 cyclists were measured over a distance of 5.0 km using biostatistical measurement technology. 347 stress situations refer directly to road infrastructure and perceived safety. In addition, data from traffic and urban planning as well as other self-collected data regarding objective traffic safety were used to assess the cycling infrastructure.

The analysis of the study shows that the objective analysis of road infrastructure and the subjective sense of safety of the cyclists are in many cases corresponding. An interesting result was that stress situations can differ in the same types of cycling facilities. A conclusion for stress and perception of safety is that constructive detail is more detached from stress triggers than the type of cycling facilities in general. An important issue is surface design. Bumps, damaged pavement and tram rails are often stressful, especially in combination with other road users. There are no clear differences in the frequency of conflicts between car drivers, pedestrians and cyclists. The number of stressful situations, in which a pedestrian was involved, was slightly predominant. Stress situations were caused through inappropriate use of cycle lanes, problems with orientation, confusing paths and a lack of acceptance of some types of cycle facilities. Base for this contribution is the bachelor thesis Road Safety from Cyclists´ Perspective (Schmidkunz, 2018).

Keywords: emotions, safety, cycling, smart sensoring, infrastructure

2 INTRODUCTION

Particularly in our cities, the high level of motorised private transport leads to problems, such as particulate pollution, noise and traffic jams. The proportion of private cars in the "modal split" needs to be reduced to guarantee future personal mobility and to protect the environment from the negative effects of transport. In this context, cycling becomes increasingly important as an environmental-friendly, emission-free and healthy alternative to car use. To increase the ratio of bicycles as a means of transport in cities, the development of cycle ways plays a central role. In recent years, different types of cycle facilities have been installed. Special attention must be paid to road safety as an essential design requirement (FGSV, 2010). However, compared to motor vehicle traffic, there are significant deficits in cycling safety research. Regarding accident research, the majority of bicycle traffic accidents are not collected due to minor material damage or injuries. Near accidents and the perceived feeling of safety are also disregarded. The latter fact becomes increasingly important in mobility concepts and guidance. However, knowledge about perception of the traffic environment and how to deal with it is comparatively low among cyclists (Platho et al., 2016). In order to increase the share of cyclists, their perspective has to be taken into account in all planning processes. For this purpose, the Urban Emotion Initiative carried out "EmoCycling" studies. EmoCycling uses electrodermal activity to identify stress situations for cyclists in road traffic. The method offers chances to close key gaps in safety research, which are necessary for planning of cycling infrastructure. For this reason, an exploratory study was carried out in the city of Augsburg with the goal of analysing the infrastructural influences on the feeling of safety.

3 STATE OF RESEARCH

3.1 Road Safety

Safety research differentiates between objective and subjective safety. While objective safety is based on obvious facts, subjective safety depends on the individual one. With regard to traffic, Klebelsberg (1982) defines objective safety as the physically measurable part. In this case, various variables such as acceleration and centrifugal forces as well as static friction play an important role. In order to consider them, vehicles and infrastructure must be planned and built according to state-of-the-art technology. With regard to cycle traffic, ERA 10 – in German "Empfehlungen für Radverkehrsanlagen, translated "recommendations for cycling infrastructure" (FGSV, 2010) represent the technical rules and regulations for the planning and construction of cycle infrastructure in Germany. The evaluation of infrastructure is mainly carried out through quantitative and qualitative analyses of accident statistics (Holte, 1994). In general, traffic facilities are described as objectively safe if there is a statistically low accident risk (Hagemeister, 2013; FGSV, 2010). Subjective safety, on the other hand, is more difficult to measure. The attribute "safe" in this context means that the cyclist considers the probability of an accident to be sufficiently low (Hagemeister, 2013). To consider the feeling of safety in planning, ERA10 recommends to avoid situations in which cyclists are endangered or overstrained and to plan cycle paths that are less dependent on the behavior of others (FGSV, 2010).

3.2 Accident research

Safety research is still closely linked to accident research, which mainly means the evaluation and analysis of accident statistics. In this context, it should be noted that a large proportion of cycling accidents are not statistically recorded. The police register only one third of bicycle accidents, i.e. accidents, in which injured persons were treated in hospitals. The number of unreported accidents with material damage or slight injuries may be much higher.

Despite these deficits, statistics show the importance of addressing road safety of cyclists. In 2016, one in four people, who died on roads in Germans towns and cities, was a cyclist (Statistisches Bundesamt, 2016). People above 65 years old are particularly at risk due to cognitive, motor skills and perceptual impairments. Main accident black spots (a place where road traffic accidents have historically been concentrated) for this age group and for children are traffic intersections (Alrutz et al., 2009). Interestingly, accident research point out that cycling is generally safer on the roadway than on separate cycle paths (Räsänen and Summala, 1998; Rodgers, 1997; Aultman-Hall and Hall, 1998). Separate cycle paths from the roadway are particularly dangerous (Bakaba, 2013), because car drivers have often difficulties to see cyclists crossing the road. Not depending on the type of cycling facilities, constructive details can lead to accidents and should not be underestimated (Alrutz et al., 2009). If accidents were caused by a cyclist, the most common cause is misconduct of the cyclist and an incorrect use of the road. According to Alrutz et al. (2009) cyclists use the wrong lane to reach their destination as quickly and directly as possible. Rule-adverse behavior due to uncertainties, like riding on the pavement where use is not allowed for cyclists, plays a less important role in statistics. However, the potential conflict with pedestrians should not be underestimated.

3.3 Psychological issues

In the past, traffic psychology focused more on motorized individual traffic than on cycling. For this reason, the most approaches and findings refer to motorists (Platho et al., 2016; Gstalter, 2009), i.e. the model of subjective and objective safety by Klebelsberg (1982). One of the main statements of Klebelsberg is that road safety is only given if the subjective safety does not exceed the objective safety. The relation of these two issues differs depending on individual learning phase and skill of every driver. In general, novice drivers overestimate themselves despite initial uncertainties in traffic situations. In this case, subjective safety is higher than objective safety and potential risks in traffic arise According to Schlag (2006), traffic situations arecharacterized through existing risks or production of risks.

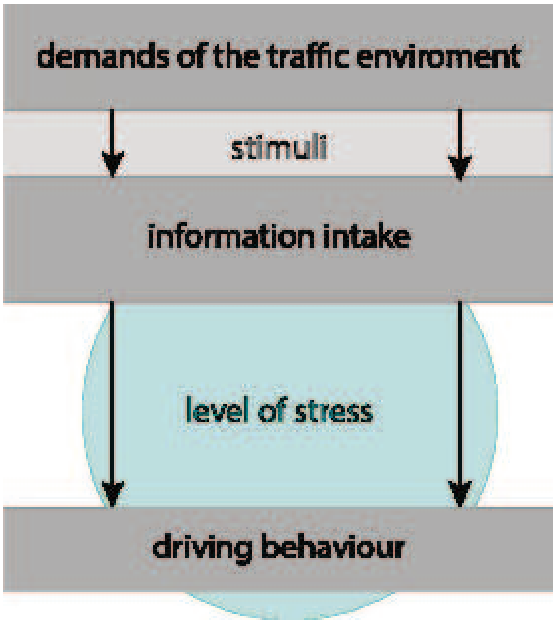

Fig. 1: traffic situation

Excessive stress can paralyze but limited stress can enable the cyclist to handle a dangerous situation (Klebelsberg, 1982). Stress leads to an increase in motivation up to a certain point. When this point is exceeded, effectiveness and productivity decrease, and stress is perceived as negative. Psychologists and physicians call it “eustress” and its opposite “distress”. According to Kreibig (2010), the negative stress is an emotional construction of fear and anger. This pattern is psychophysiological visible when electrodermal activity increases and shortly afterwards skin temperature decreases (Bergner et al., 2011). Within the framework of the EmoCycling concept, these parameters of cyclists are measured and spatially located to identify stress situations in city traffic.

4 EMOCYCLING AUGSBURG

Test area for the applied concept was the city of Augsburg with a test track around the inner city with different types of road and cycling infrastructures.

4.1 Study area/selected track Augsburg

The city of Augsburg applied for the project “Fahrradstadt 2020 (bicycle city 2020)”, initiated by ADFC (German Bicycle Club) and was integrated in the “Local Agenda 21” process. Aim of this initiative was to develop Augsburg until 2020 as a bicycle friendly city by increasing the percentage of cyclists from 15 percent in domestic traffic up to at least 25 percent in 2020. Increasing the number of new cyclists should be at the cost of public transport. Strengthening the bicycle as a mode of transport in everyday life and increasing traffic safety are additional goals of the project. Against this background, the study analyses different criteria concerning quality, types and condition of cycling infrastructure and is oriented towards usual times of a typical daily bike ride. Interesting points of investigation are the already realized bicycle corridors as well as road segments with high traffic densities and rerouting traffic away from the main (bicycle) routes.

The test track (fig.2) was developed by examination of official cycling plans, own observations, consultation with members of ADFC and proofing the estimated numbers of cyclers with the help of databases from STRAVA (Strava Inc., 2018), Bike Citizens (Bike Citizens, 2018) and RADar! (Klima-Bündnis der europäischen Städte, 2018). At the counting station, “Konrad-Adenauer-Allee” around 1700 bicycle riders pass a day.

The entire journey starts/ stops from/at the Grand Hotel Cosmopolis. The first 500 meters of the test drive will not be used for the evaluation because this part serves as “calm-down” section, where people can relax during their first few meters of the journey. A lot of studies observed an increased level of stress in the beginning due to the unfamiliar situations (Núñez , Javier Y. M.. and Rodrigues da Silva, 2017; Zeile et al., 2016; Höffken et al., 2014).

ISBN 978-3-9504173-6-4 (CD), 978-3-9504173-7-1 (print)
Editors: M. SCHRENK, V. V. POPOVICH, P. ZEILE, P. ELISEI, C.BEYER, J. RYSER

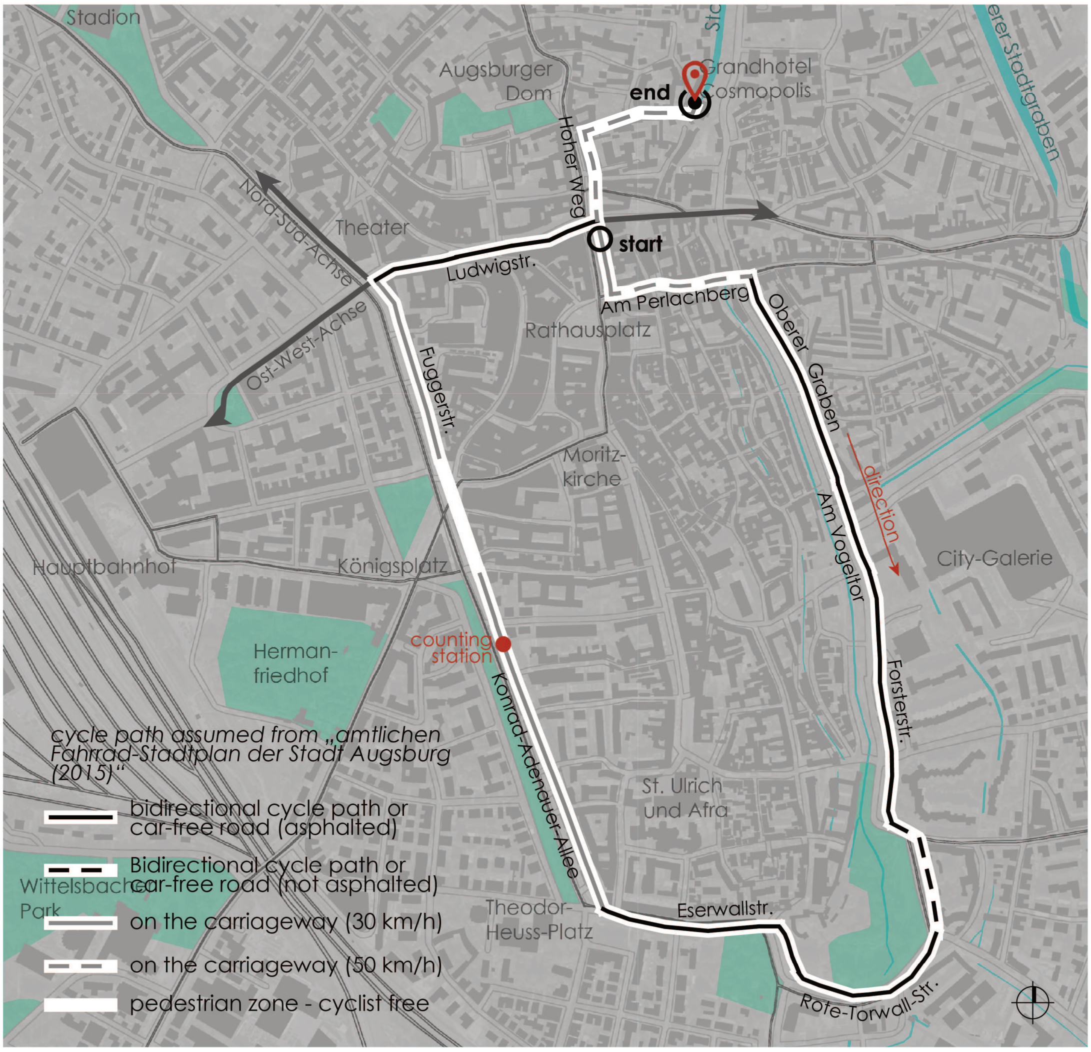

Fig. 2: Test area in the city of Augsburg

4.2 Measurement method

Recruitment of the participants had no specific requirements, provided that all have the ability to ride a bike: Due to the exploratory character of the research set-up, a sufficient population of 30 persons took part in the study (n = 30), heterogenous in age, driving skill and sex. For example, there were in total 14 women and 16 men between the ages of 14 to 67 years. We chose a mixed-/multi-method approach following the works of Gross & Zeile (2016) and Rockenbach (2018), conducting an analysis of objective and subjective traffic safety. The track should not be longer than 5.5km, which is the mean average of a usual daily ride (Groß, 2015).

Analysis of objective safety includes a survey of the cycling infrastructure, road surface condition, vibration, mean speed, etc., enriched with information (fig.1) from official the cycling map Augsburg (Augsburg, 2015).

For detecting the subjective or "objectified" safety, test riders are equipped with a Smartband from "Bodymonitor Sensing (BMS)", a GPS tracker "i Blue 747" from "Transsystems" and a GoPro Hero video camera. It was recommended to ride their own bike to exclude influences due to a uncomfortable riding situations. Anyway, in exceptional cases even a loan of a bicycle was possible.

The Smartband is attached to the left forearm with two small, self-adhesive, electrodes. Among other things, the skin conductivity (electrodermal activity) and temperature for the identification of negative stress (Zeile et al., 2011) are measured in the frequency of 10 Hertz (Hz). All participants carry a GPS tracker to measure the exact position (latitude and longitude) and recording time stamp (hh: mm: ss), in 1 HZ, to locate the stress measurements .

Third measuring device is the action cam GoPro Hero, worn on the upper body with a chest strap. With the help of the video recordings, observation and analysis of stress belonged situations from an ego-view for a categorization is easier. Based on the model describing traffic situations (see chapter 3.3), the following data are collected: Stress triggers from traffic environment, distinguishing bicycle infrastructure (surface design, obstacles, etc.) and road users (overhauling vehicle, etc.), stimuli and information (tactile, acoustic or visual) as well as riding behavior. By categorizing them, it is possible to highlight stress situations due to the influence of bicycle infrastructure.

Last data collection method is a questionnaire to collect information about subjective traffic safety. Content are quantitative elements concerning sociodemographic issues, reasons and attitudes, as well as self-assessment of stress situation in a ranking (von Below, 2016). In the qualitative part, participants are asked to rate retrospectively their personal stress points (Fig. 2) with a short explanation (Dörrzapf et al., 2016; Groß, 2015).

4.3 Analysis and results

The measuring section is close to or in the city center and is characterized by high percentage of public transport and pedestrians. All types of cycle infrastructure are conform to ERA 10, differing only in quality and requirements for the bicycle rider. For a better comparison, the track is divided into 18 sections. Potential danger zones could be: 1) poor surface, 2) rails crossing cycling infrastructure, 3) stations /stops of public transport, 4) frequency of nodes in 100m segments, 5) turning points, 6) lack of safety distance to parking or driving cars, 7) to small profile of cycling infrastructure according ERA.

For the individual sections of the route, all criteria were checked and the potential risks were summed up. As shown in Figure 2, Sections S1, S2, S6, S13, S16 and S17 call for special attention from the cyclist while the other sections have little potential danger zones.

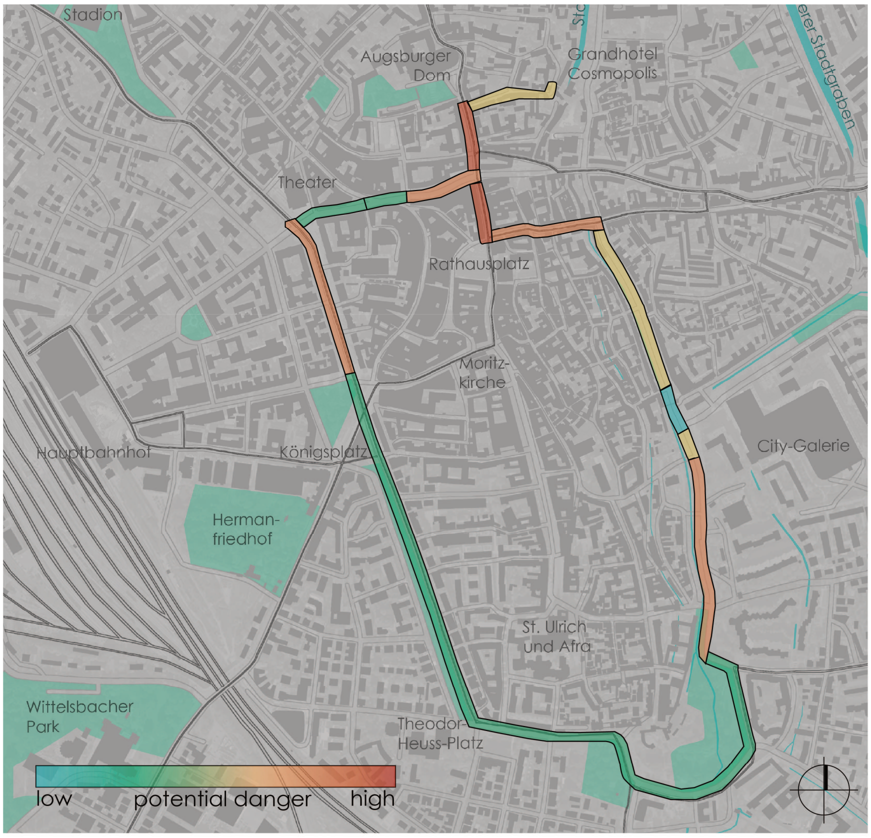

Fig. 3: aggregation of self estimated stress situations after the test rides

Analysis of stress measurement with support through video recordings delivers an adjusted heatmap reducing the phenomena of “personal noise” (triggered stress points, which do not belong to cycle infrastructure). In numbers: from a total amount of 1040 stress triggers, after reducing “personal noise”, 635 triggers related to traffic remained. After a second revision, 347 replies directly referring to the test setting / research question concerning cycle infrastructure were left.

ISBN 978-3-9504173-6-4 (CD), 978-3-9504173-7-1 (print)
Editors: M. SCHRENK, V. V. POPOVICH, P. ZEILE, P. ELISEI, C.BEYER, J. RYSER

In general, we identified two main stress categories (fig. 3): riding behavior to arrive at a destination (main stress trigger is how to turn or change direction) and adopting personal riding behavior (braking, accelerating as a reaction to a trigger). Some other interesting facts were that

- stress triggers were often caused by a combination out poor cycling infrastructure and behavior of other transport users,
- a high percentage of 35% of stress triggers was caused through surface quality and design.
- Conflicts between pedestrians and cars are occurred more often than with other bicycle riders
- Unexpected high percentage of stress triggers between pedestrians and cyclers who drove at their own separate lane
- Tactile and visual perceptions are also stress triggers

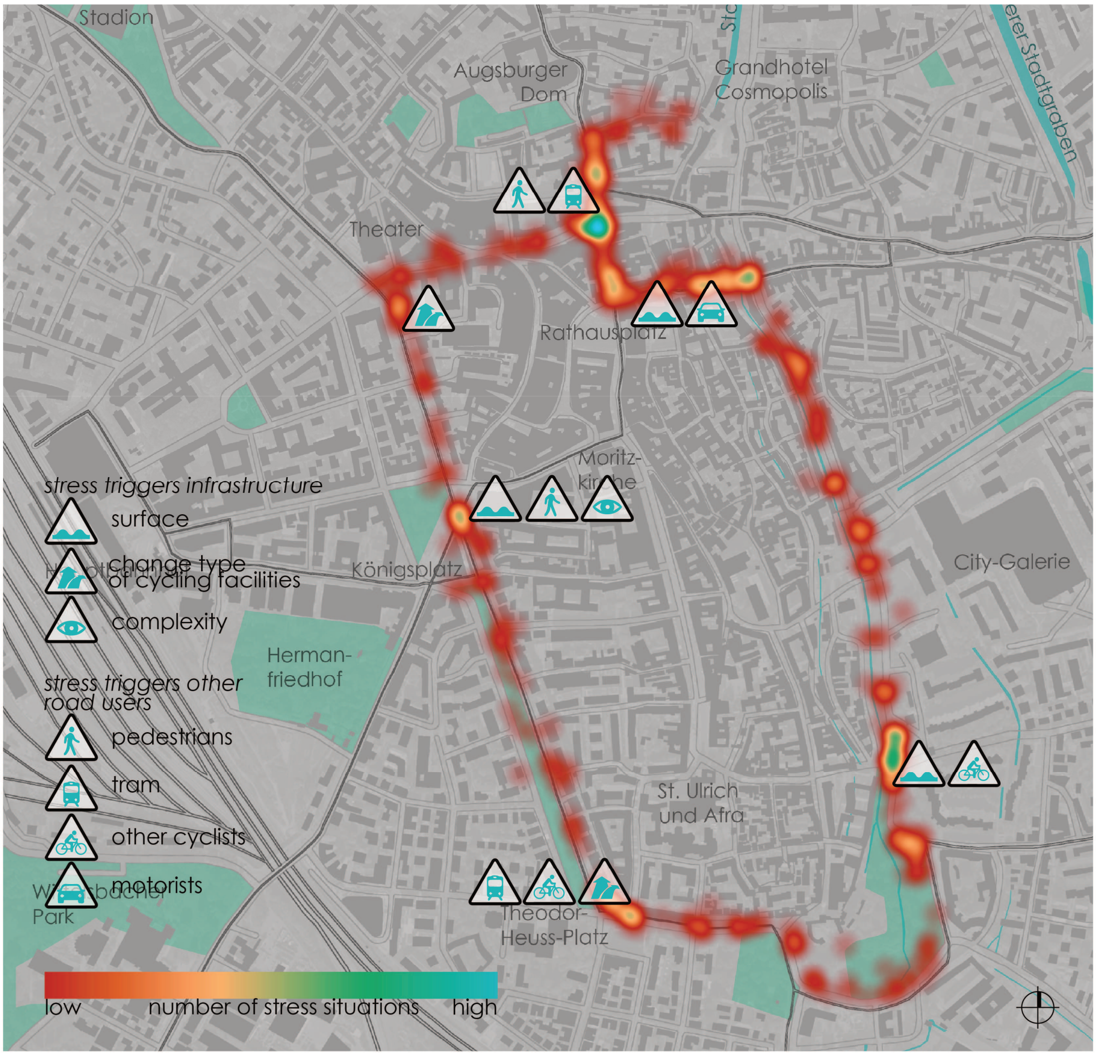

Figure 4: Heatmap of stress triggers after reducing personal noise and attributing cycling related attributes

These findings were supported by the questionnaire (n=26), which was only an explorative study and not representative, the peer group 26-40 years and the daily cycle riders were overrepresented. Notwithstanding the above, test persons locate potential stress situations concerning pedestrians, surface conditions and nodes (fig. 4). As a result, there was a close match between the two approaches (questionnaire and stress measurement) in the results of the different track segments, especially in those with bad surface conditions. Most differences occur at Königsplatz - people got more stress triggers than they expected to have - and in Fuggerstraße. Interestingly, people expect more critical situations caused through high densities of nodes, parking cars and surface conditions.

Fig. 5: Mapped perceived personal stress situations after the test ride

5 DISCUSSION

The presented results give a good insight into the topic of perceived stress related to cycling infrastructure. Some critical remarks have to be done: All the tracks presented an artificial situation, i.e. “real-life” situations could differ. Regarding “objective dangerous situations” like junctions or access, it can be discussed that a change in surface structure is useful, especially if planers take into account the behavior model by Klebelsberg (1982), which implies, that traffic safety is only guaranteed if the subjective safety does not exceed the objective one. In other words, it is important that cyclers do not have a false sense of security, especially if this is not the case in an objective analysis. A consistent design of cycling infrastructure is necessary, good examples with red or blue lanes for cyclers increase the safety for bicycle riders. Cities should follow the guidelines in ERA 10 – in German “Empfehlungen für Radverkehrsanlagen, translated “recommendations for cycling infrastructure” (FGSV, 2010). Some stressful situations were caused by “irregular behavior” of cyclists.The question is, if these behaviors are caused by planning errors not offering direct connections. A closer look into the risk of accidents, structural and operational characteristics, play a greater role in the density of stress situations than the type of cycling infrastructure itself.

6 CONCLUSION

One trendis clear to see: condition and type of cycling infrastructure influence subjective perceived safety. The method of psychophysiological monitoring in combinatin with surveys according to cycling infrastructure – the so called emocycling – is helpful to get new insights into perceived safety and traffic security. Due to the experimental setup and the still semiautomatic data analysing process and a lack of consumer products, which can measure the needed biostatistical data, application and handling of the emocycling method is still tricky and not suitable for mass application. Our peer group of 28 cyclists gives a good idea of the potential and application of the methods. However,the vision to have a group of volunteers with a permanent datastream to gather cycling infrastructure issues is still not solved. Feeling comfortable and safe during a bike ride, is essential for convincing people to start riding bikes.The other key issue is to reduce travel times and increase the speed of getting from A to B. Balancing perceived safety and travel times is key for a succesful bicycle strategy.

7 ACKNOWLEDGEMENT

We would like to express our gratitude to the German Research Foundation (DFG – Deutsche Forschungsgemeinschaft) and the Austrian Science Fund (FWF) for supporting the project "Urban Emotions" (DFG reference number ZE 1018/1-1, FWF reference number I-3022).

Another gratitude to the test riders in Augsburg, and the Grand Hotel Cosmopolis in Augsburg, which was the base station during the study.

8 REFERENCES

ALRUTZ, D., BOHLE, W., MÜLLER, H., AND PRAHLOW, H.: Unfallrisiko und Regelakzeptanz von Fahrradfahrern. Wirtschaftsverl. NW Verl. für neue Wiss, Bremerhaven. 2009.

AUGSBURG, S.: Amtlicher Fahrrad-Stadtplan Augsburg: Fahrrad-Stadtplan 1:15.000, Fahrrad-Innenstadtplan 1:7.500, Fahrrad-Routenplan 1:45.000, Straßenverzeichnis. 2015.

AULTMAN-HALL, L. AND HALL, F.L.: Ottawa-Carleton commuter cyclist on- and off-road incident rates. Accident Analysis & Prevention, 29–43. 1998.

BAKABA, J.E.: Sichere Knotenpunkte für schwächere Verkehrsteilnehmer. 2013.

VON BELOW, A.: Verkehrssicherheit von Radfahrern - Analyse sicherheitsrelevanter Motive, Einstellungen und Verhaltensweisen. Wirtschaftsverlag NW, Bremen. 2016.

BERGNER, B., ZEILE, P., PAPASTEFANOU, G., AND RECH, W.: Emotionales Barriere-GIS als neues Instrument zur Identifizierung und Optimierung stadträumlicher Barrieren. 430–439. 2011.

BIKE CITIZENS: Augsburg. https://www.bikecitizens.net/de/staedte/augsburg/ 2018.

DÖRRZAPF, L., BERGER, M., DORNER, F., ET AL.: Fühl die Stadt - Methoden zur Erfassung subjektiver Wahrnehmung. In: 2016.

FGSV: Empfehlungen für Radverkehrsanlagen (ERA). Köln. 2010.

GROß, D.: EmoCyclingConcept - Potentiale der emotionalen Stadtkartierung für Radverkehrskonzepte am Usecase Worms. 2015.

GROß, D. AND ZEILE, P.: EmoCyclingConcept -- Smart and Safe Mobility -- Workshop. In: M. Schrenk, V. Popovich, P. Zeile, P. Elisei and C. Beyer, eds., REAL CORP 2016. Wien, 237–242. 2016.

GSTALTER, H.: Verkehrspsychologie. In: Handwörterbuch Psychologie. Beltz, Weinheim, 822–827. 2009.

HAGEMEISTER, C.: Objektive Sicherheit versus subjekitves Sicherheitsgefühl. 3. Nationaler Radverkehrskongress. 2013.

HÖFFKEN, S., WILHELM, J., GROß, D., BERGNER, B.S., AND ZEILE, P.: EmoCycling -- Analysen von Radwegen mittels Humansensorik und Wearable Computing. In: M. Schrenk, V. Popovich, P. Zeile and P. Elisei, eds., Real CORP 2014. Wien, 851–860. 2014.

HOLTE, H.: Kenngrößen subjektiver Sicherheitsbewertung. Bremerhaven. 1994.

KLEBELSBERG, D.: Verkehrspsychologie. Springer-Verlag, Berlin Heidelberg. 1982.

KLIMA-BÜNDNIS DER EUROPÄISCHEN STÄDTE: RADar! - Die Meldeplattform für Radverkehr. https://www.radar-online.net/home/ 2018.

KREIBIG, S.D.: Autonomic nervous system activity in emotion: A review. Biological Psychology 84, 3, 394–421. 2010.

NÚÑEZ , JAVIER Y. M.. AND RODRIGUES DA SILVA, A.N.: Assessment using smartphone sensors and a geographic information system. In: Proceedings of CUPUM2017. Adelaide. 2017.

PLATHO, C., PAULENZ, A., AND KOLREP, H.: Wahrnehmungspsychologische Analyse der Radfahraufgabe. Bremen. 2016.

RÄSÄNEN, M. AND SUMMALA, H.: Attention and expectation problems in bicycle-car collisions: an in-depth study. Accident Analysis & Prevention, 657–666. 1998.

ROCKENBACH, I.: EmoCycling. Individuelles Sicherheitsempfinden von Radfahrenden in Karlsruhe. 2018.

RODGERS, G.B.: Factors associated with the crash risk of adult bicyclists. Journal of Safety Research, 233–241. 1997.

SCHLAG, B.: Risikoverhalten im Straßenverkehr. Wissenschaftliche Zeitschrift der Technischen Universität Dresden, 35–40. 2006.

SCHMIDKUNZ, M.: Verkehrssicherheit aus der Sicht der Radfahrer: Studie über den Einfluß der Radinfrastruktur in Stressituationen. 2018.

STATISTISCHES BUNDESAMT: Straßenverkehrsunfälle - Kraftrad- und Fahrradunfälle im Straßenverkehr 2016. 2016.

STRAVA: Strava Global Heatmap. 2018. https://www.strava.com/heatmap#11.71/10.86133/48.35852/hot/all 2018.

ZEILE, P., RESCH, B., LOIDL, M., PETUTSCHNIG, A., AND DÖRRZAPF, L.: Urban Emotions and Cycling Experience – enriching traffic planning for cyclists with human sensor data. GI_Forum 1, 204–216. 2016.

ZEILE, P., RODRIGUES DA SILVA, A.N., AGUIAR, F. DE O., PAPASTEFANOU, G., AND BERGNER, B.S.: Smart Sensoring as a Planning Support Tool for Barrierfree Planning. Proceedings 12th International Conference on Computers in Urban Planning and Urban Management (CUPUM) University of Calgary, 1–16. 2011.