Shedding Light on the Dark-Field of Cyclists’ Safety Critical Events: A Feasibility Study in Germany

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ABSTRACT

Experts assume that the dark-number of non-registered less severe cyclists’ incidents that do not result in hospitalisations such as near misses or safety critical events (SCE) is vastly greater than the number of registered accidents. There are only few studies, which make estimates on the extent of this so-called underreporting. To our knowledge, there is neither an instrument nor a study that provides objective and precise information on the dark-number. Existing studies in this context mainly used survey instruments of subjective character, which might be constrained by recall biases. Therefore, the aim of our study was to develop and evaluate an instrument that assesses SCEs objectively in a natural context. On basis of a literature research based definition for SCE an observation instrument was developed. It can be used to examine situations regarding factors like number, type and behaviour of involved interaction partners, reasons for single-bicycle accidents or cyclists’ follow-up reactions (i.e. deceleration, evasion, loss of stability). In order to evaluate the instrument, a one-week field study was conducted in Chemnitz (Germany) in November 2019. The traffic hub locations for the cyclist observations were changed for each weekday. From 1202 passing cyclists, 17 cyclists could be observed having a SCE. Typical characteristics of the observed SCE comprised cross traffic as well as overtaking manoeuvers being performed with insufficient safety margins and were mainly initiated by a car driver. As a consequence of the SCE, cyclists frequently had to brake or showed evasion manoeuvers in order to avoid a crash. Even though SCE occurred rarely, we succeeded in assessing the objectively existing SCE using the developed instrument. However, besides rating situations as safety critical, it is also important to include cyclists' subjective sense of safety to depict SCE completely and in turn, to foster the improvement of cycle traffic safety.

Keywords: cycling, safety critical events, dark figure, observation, field study.

1 INTRODUCTION

Cycling has gained a lot of popularity in the last years. Not only does it keep healthy and physically fit, it is also eco-friendly. This is an important aspect in terms of the need of rethinking environmental behaviour. According to the German Federal Ministry of Transport and Digital Infrastructure (2019), this positive trend is reflected, for example in the steadily increasing bicycle stocks in Germany. Compared to the year 2009, an increase of almost 7 million bicycles was recorded ten years later in 2019 (Statista, 2020). In addition, the frequency of Germans using the bicycle increased from 41% in 2017 to 44 % in 2019. The main purpose of bicycle use was covering short distances (Borgstedt et al., 2019). Contrary to the expectation of the safety in numbers effect (Jacobsen, 2003; assumption: a lower probability of cyclists being injured by motorist the more people bicycle), growing bicycle traffic volume concomitantly caused more conflicts and in turn, growing numbers of road fatalities in Germany (UDV - GDV, 2020). Of all casualties that were recorded by the police in Germany in 2018, cyclists represent 22 % (Statistisches Bundesamt, 2019). In comparison to the previous year, this amount is up by 2 %. Likewise the number of cyclists' fatalities increased by 3 % in Germany between 2010 and 2018. This trend is reflected throughout Europe as well (European Commission, 2018). However, these statistics need to be considered under reserve, as they do not depict the actual number of accidents with the involvement of cyclists. By now, cyclists’ accident statistics refer to reports that were generated by the police or in a hospital. The statistics do not cover less severe incidents and safety critical events of cyclists in which, e.g. hospitalisation was not necessary. Due to the large accident numbers, it can be assumed that the dark-number of non-registered accidents and safety critical events (SCEs) is large as well. Since determining the rate of the so-called *underreporting* is very sophisticated, there are only few studies that deal with this issue (e.g., Winters & Branion-Calles, 2017; Shinar et al., 2018; von Below, 2016). Estimations on the extent of the underreporting rate vary for different countries. Von Below (2016) states that the rate is by about 70 % and for single-bicycle accidents it is expected to be considerably larger. Further, estimations on the extent of the underreporting rate vary for different countries. Due to country specific regulations on accident registration, infrastructural or also cultural differences, knowledge gained from international research on the underreporting rate of cyclists’ accidents and cyclists’ SCEs might not be transferable to Germany. In order to develop measures to foster traffic safety it is important to gain insight into the prevalence of SCEs or the number of near-accidents that are not reported. To date, infrastructural changes in particular require numeric proof of e.g., concrete incident rates (Winters & Branion- Calles, 2017). Indeed, there is no standardised definition of such SCEs, nor is there any instrument that would enable a situation to be assessed as safety critical. Therefore, this paper deals with the definition of SCEs as well as with the development of a universally applicable observation instrument and its Proof of Concept within the scope of a field observation.

1.1 Definition of SCEs

In the existing literature on SCEs, different wordings and definitions are used to describe such events. ‘Conflicts’, ‘near misses’, ‘uncomfortable situations’, ‘annoying or frightening events’ are some examples. Common to all is that the incidents that we summarise as safety critical do **not involve severe physical injuries** causing hospitalisation (e.g., Heinrich et al., 1980; Kolrep-Rometsch et al., 2013; Sanders, 2015; Aldred, 2016; Puchades et al., 2018). Further, it is differentiated whether cyclists' SCEs are treated as incidents involving at least one **interaction partner** (e.g., Sanders, 2015; Kolrep-Rometsch et al., 2013; Reynolds et al., 2009; Fuller et al., 2013) or additionally include **single-bicycle incidents** (e.g., Werneke et al., 2015; Joshi et al., 2001, Aldred, 2016). Besides, Joshi et al. (2001), Poulos et al. (2017) as well as Kolrep-Rometsch et al. (2013) describe that often a **change in behaviour** is carried out by the cyclist **in order to prevent a collision** with another road user. This **collision avoidance behaviour** thus may manifest in a **decreased or increased velocity**, recognisable by a pedalling stop/ breaking or faster pedalling, but also by a **spontaneous change in driving direction**, recognisable by jerking the bicycle handlebar (Kolrep-Rometsch et al., 2013; Poulos et al., 2017, Guo et al., 2010). In this context, Rockenbach et al. (2019) address the violation of traffic rules, which in former studies that base on self-reports is underrepresented (e.g. Werneke et al., 2015; Schleinitz et al., 2015) and might be owing to a social desirability bias. Therefore, the definition for SCEs should also comprise situations that **force** cyclists to **change their behaviour,** which can either be reflected by the cyclists' violation of traffic rules, or which serves as a compensatory action elicited by the violation of traffic rules by other road users. For **single-bicycle incidents** however, the **loss of stability** seems to be an important aspect (Dozza & Werneke, 2014; Werneke et al., 2015; Schepers & Klein Wolt, 2012). Referring to Werneke et al. (2015), we further differentiate single-bicycle SCEs depending on actually losing or degrading stability, respectively. When ***losing stability***, cyclists either have to stop over and descend from the pedals in order to rebalance before continuing, or cyclists fall off the bike without sustaining physical injuries that lead to hospitalisation. When ***degrading stability***, cyclists can rebalance and continue their journey without descending from the bicycle. Schepers and Klein Wolt (2012) found in this context that about half of the single-bicycle incidents are due to unfavourable infrastructure conditions. More precisely, these were for example collisions with obstacles, poor or slippery road surface conditions, risky cycling behaviour or external forces like a sudden gust of wind.

Summarising these findings, we define cyclists' safety critical events as follows. Safety critical events are situations that cause cyclists to take an evasive action (change of direction or velocity) in order to avoid collisions with other road users or objects, respectively these are situations in which cyclists are being forced to change their behaviour (e.g., violation of traffic rules by other road users). Furthermore, safety critical events can be single-bicycle incidents that comprise the degradation or total loss of stability, which may entail a fall, but do not result in such a physical injury of the cyclist as it required a treatment in hospital.

1.2 Previous approaches for the assessment of SCEs

Observations and Naturalistic Cycling Studies (NCS), for example are methods that have already been applied in the context of assessing SCEs. Contrary to cyclists' subjective impressions, such as self-reports, these methods benefit from an independent rater judgement of cyclist behaviour in a natural environment, which is based on predefined criteria. In a NCS by Schleinitz et al. (2015) participants' bicycles were endowed with video cameras for a duration of 4 weeks for which the cyclists were instructed to use their bicycle as usual. The annotation of video footage focused on SCEs that occurred during interactions with other road users. For the classification of SCE the authors used Reynold's et al. (2009) definition of a conflict which highlights the necessity "to change speed or direction to avoid a collision" (p. 4). According to this definition, cyclists experienced 1.44 SCEs per 100 km travelled on average (Schleinitz et al., 2015). As Schleinitz et al. (2015) had a small sample size (*N* = 31) and subjects were allowed to choose their cycling routes on their own, the results lacks of representativity and therefore of external validity. Kolrep-Rometsch et al. (2013) chose a combined approach of observations and on-site interviews with passing cyclists. In their study they focused on the prevalence of conflicts between cyclists and car drivers during turning manoeuvres. A total of 43 traffic junctions in 4 different German cites were observed for 3 hours each. For the observation, conflicts were divided into slight and severe conflicts. The results showed a conflict rate of 10 %, which means that every tenth interaction between a cyclist and a car driver was at least slightly critical. Eventually, an expanded time span for observation may have revealed a greater number of SCEs and thus, a more precise image of its prevalence might have been drawn.

Besides the excerpt of studies presented employing behavioural data to assess the prevalence of SCEs, the few studies existing above in this context mainly employed methods focusing on cyclists’ subjective impression (e.g., questionnaires, interviews, or diary studies).

In a diary study where cyclists were supposed to record the number of SCEs, Aldred and Goodman (2018) for example found that in 2014, British cyclists experienced 2.6 SCEs per day (2015: 1.8 near misses/day). Results from another British diary study (Joshi et al., 2001) showed that on average cyclists had one SCE each 5.59 miles cycled. Furthermore, Poulos et al. (2017) stated that in their diary study with Australian cyclists, one or more SCEs were experienced on 10 % of the recorded cycling days. Per 1000 hours cycling a mean of 105.2 SCEs and per 1000 km distance travelled a mean of 5.04 SCEs was recorded by the diarists. With regard to official crash rates provided by hospitals and excluding overnight hospital stays, Poulos et al. (2017) indicated that the SCE rate is more than 200 fold higher, which suggests a large dark-number of SCEs. Using a self-report online questionnaire, Sanders (2015) show that 86 % of annually cycling US-American bicyclists had experienced at least some type of SCE out of a number of SCE and collision types. As part of another online questionnaire study (Puchades et al., 2018), cyclists from Italy were requested to indicate on a scale ranging from 0 to 4 (0 – never, 4 – 4 times or more) how frequently they experienced SCEs in the last year. On average participants experienced 1.32 SCEs. Besides, an Australian online questionnaire on physical injuries due to cycling revealed, that 27 % of the respondents have had one or more cycling injuries in the previous year and only 9.2 % stated, that they had reported their most severe injuries to the police (Heesch et al., 2011). For these research results a country comparison is only possibly to a limited extent due to different definitions and the different reference values.

In sum, existing study results show that research in the context of assessing cyclists' SCEs yet is not sufficiently exhausted. Depending on research methods (e.g., NCS, observation, self-reports, interviews) and focus of research (e.g., number and/ or type of cycling injuries, accidents, and SCEs at certain traffic junctions, in certain time spans, at certain distance travelled), the number of identified SCEs varies vastly. A reason for the differences might be that neither a unified scientific definition for SCEs for both, interactions with other road users and single-bicycle SCEs existed by now, nor was there an SCE-assessing instrument that aggregates the criteria of previous research in this topic and that allows the determination of the dark-number of SCEs.

1.3 Assessment of SCEs

In order to asses SCEs according to our definition (s. 1.1), adequate criteria need to be determined that allow a precise specification of SCEs. With regard to the definition of SCEs, for near misses and single-bicycle SCEs a first categorisation can be made concerning the presence of an interaction partner (IP) (s. Figure 1).

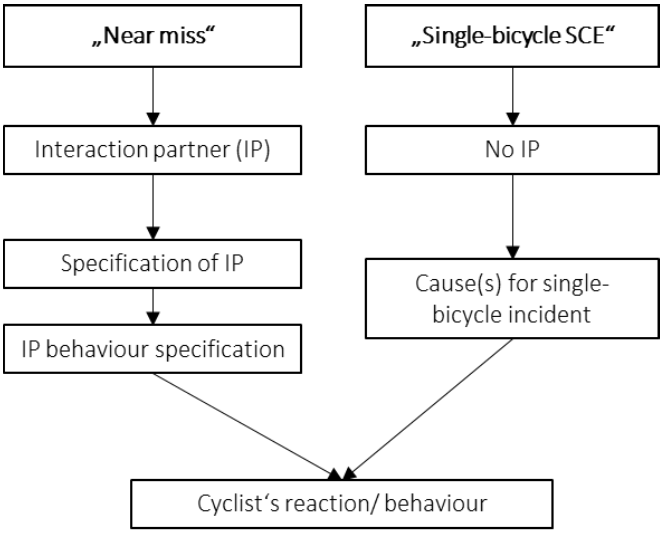

Figure 1. SCE specification scheme for near misses and single-bicycle incidents.

In case a SCE occurred involving an IP (**near miss**), the *type of IP* as well as the *IP's behaviour* that led to the SCE is to be *specified.* For the description of single-bicycle SCEs, categories and corresponding criteria identified and used by (Nelson et al., 2020) as well as by Schepers and Klein Wolt (2012) provide the basis. Infrastructural conditions as well as risky and inadvertent cycling behaviours were found to *cause single-bicycle SCEs*. Finally, the outcome of the SCE (independently from whether classified as near miss or single-bicycle SCE) can be determined by specifying the cyclist's reaction or behaviour to it. As in 1.2, criteria reflecting *reactions to SCEs* can be loss of stability with or without falling (Dozza & Werneke, 2014; Werneke et al., 2015; Schepers & Klein Wolt, 2012), evasion manoeuvers (Poulos et al., 2017), spontaneous deceleration or acceleration (Kolrep-Rometsch et al., 2013; Guo et al., 2010), and compliance with traffic rules.

In order to understand the emergence of SCEs to a greater extent, further potential influencing factors should be included in an instrument that assesses SCEs (e.g., Poulos et al., 2017). We identified the following factors as relevant as former research indicates their impact on the occurrence of SCE and accidents, respectively as well as on frequency of bicycle use: 'time of day' (e.g., Aldred & Crosweller, 2015; Aldred & Goodman, 2018; Poulos et al., 2017), 'season' (e.g., Statistisches Bundesamt, 2018), 'weather conditions' (e.g., An et al., 2019), 'traffic density' (e.g., Nordback et al., 2014; Alrutz et al., 2015). For the factors 'age' and 'gender' findings are diverse and thus, they should be included as well.

We aim at implementing the determined criteria into an instrument that allows the documentation of observations, which is supposed to be made publicly available and thus, can be universally employed in further cities for the evaluation of various traffic situations. Thereby, we expect to shed more light on the dark-field of cyclists' safety critical events. In this paper, we present the results of a feasibility-study conducted to evaluate the applicability of the observational instrument, which will be applied for a German-wide representative observation study (observation for 12 weeks in 3 German cities at 4 different traffic junctions).

2 METHOD

2.1 Observation instrument

The developed instrument for the observation in form of a checklist was used to document the observed SCEs precisely according to the scientific definition (cf. 1.1) and the determined categories (cf. 1.3). In sum, the instrument consists of six main parts or categories, respectively. The main parts as well as corresponding SCE-indicating criteria identified base on our comprehensive literature research and are listed in the following:

(1) Observational boundary conditions and demographic characteristics:

- *Time of situation* (e.g., Aldred & Crosweller, 2015; Aldred & Goodman, 2018; Poulos et al., 2017)*, date* (e.g., Statistisches Bundesamt, 2018)*, city*
- *Cyclist's characteristics*:
    - Gender: female, male, diverse

    - Age group (estimated, in years): 0-6, 7-10, 12-13, 14-19, 20-29, 30-39, 40-49, 50-59, 60-69, 70-79, 80 + (Nobis, 2019)
- *Bicycle characteristics*:
    - Bicycle type: City-bike, trekking/ mountain bike, racing bike, carrier bike, child's bike, miscellaneous
    - Pedelec/ motorised
    - Cycling with: trailer, infant seat, helmet
- *Traffic density*: estimation on a 10 point Likert scale ranging from '1 = no traffic' to '10 = congestion' (e.g., Nordback et al., 2014; Alrutz et al., 2015)

(2) SCE involving an IP

- *IP's behaviour*:

  In Table 1 criteria to describe IP's behaviour is summarized according to literature findings. In addition to this, the instrument includes the category 'miscellaneous'.

Table 1. Literature based summary of criteria to describe IP's behaviour.

Summarised criteria	***Reference from literature***			
	Aldred & Crosweller (2015), Aldred (2016)	*Poulos et al. (2017)*	*Sanders (2013)*	*Nelson et al. (2020)*
Undersized distance (overtaking)	*x*	*x*	*x*	*x*
Tailgating	*x*	*x*	*x*	*/*
Aligning closely	*x*	*/*	*/*	*x*
Blocked cycle path	*x*	*/*	*x*	*x*
Near-dooring	*x*	*/*	*x*	*/*
Aggressive behaviour (other IPs, cyclist itself)	*/*	*/*	*/*	*x*
Cross traffic (from the left/right)	*x*	*x*	*x*	*x*
Frontal approach	*x*	*/*	*x*	*/*

Note: 'x' stands for criteria found and '/' for criteria not found in the respective reference.

- *Type of IP(s) being involved in SCE:*
  - Car, truck, motor cycle, bus, tram, e-scooter, other cyclist, pedestrian animals (e.g., Werneke et al., 2015; Nelson et al., 2020)
  - Miscellaneous

(3) SCE not involving an IP

- *Infrastructural conditions:* kerb, tracks, pothole, uneven road surface, glazed frost, leaves, rubber mats surrounding kerbs, and luggage (Nelson et al., 2020; Schepers & Klein Wolt, 2012)
- *Risky and inadvertent cycling behaviours:* getting caught in (clipless) pedals, smartphone use while riding, or freehand riding (Nelson et al., 2020; Schepers & Klein Wolt, 2012)

(4) Cyclist's behaviour

- *Degrading stability without falling*, *degrading stability with falling*, *evasion manoeuver*, *spontaneous deceleration*, and *spontaneous acceleration*

No further distinction was made in the instrument for these categories. Preliminary observer training included examples for possible observable indications that allow classifying a situation as safety critical (cf. 0).

- *Compliance with traffic rules:*
  - Yes/no
  - Not using available cycle path, illegally cycling on pedestrian way/ in pedestrian area, ghost riding (wrong driving direction), riding two abreast and impeding other road users, red-light-running, smartphone use, not using front and/or back light, neglecting step speed, hands-free cycling (German Highway Code), miscellaneous

(5) Participation in a follow-up interview

The interview is part of the observational study as whole, but will not be addressed in the present paper.

(6) Weather related factors

- *Cloudiness*: sunny, cloudy, dull (e.g., An et al., 2019)
- *Rainfall*: no, light, heavy, snow, fog, gale (e.g., An et al., 2019)
- *Street*: dry, wet, iced, slippery
- *Temperature, sunrise, sunset, location of observation, observer name*
- Space for *comments*

2.2 Procedure

2.2.1 Recruitment

Preliminary information on the study was disseminated through different media, including reports in local newspapers, in social media and on radio. As broached above, the observation study as a whole was composed of the observation per se and interviews with cyclists. Thus, the purpose of disseminating preliminary information was to increase the cyclists' willingness to participate in the interview and to remove barriers. In order not to bias the incidence of SCEs, the concrete observation area and the purpose of observing SCEs was excluded from the information.

2.2.2 Observation and training

The field observation was carried out on 5 weekdays in November 2019 from 7.00 am to 5.00 pm at 5 urban traffic junction locations in Chemnitz (Germany), which were changed for each weekday. Figure **2**2 shows the selected traffic junctions and corresponding observation areas. The traffic junctions comprised a (1) separated bike lane with extra separation of an adjacent pedestrian path, (2) bike box at a signalised intersection, (3) mixed-traffic roundabout (without a dedicated bike lane), (4) through bike lane at a signalised intersection and (5) separated bike lane with adjacent bus stop shelter.

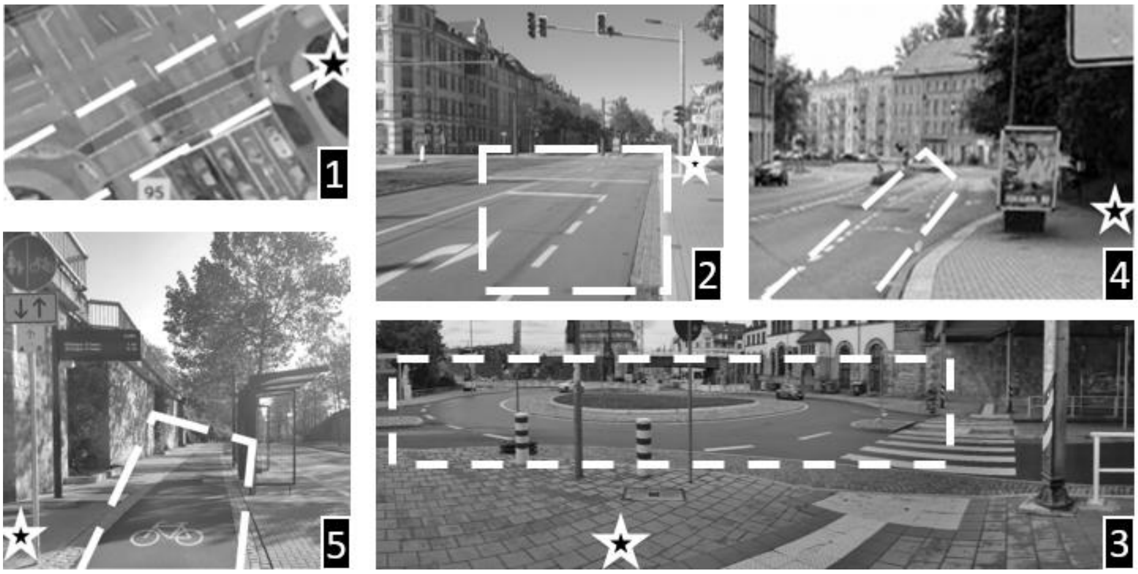

Figure 2. Traffic junctions (1-5), predefined observation areas (dashed line), and observer locations (star) (1: Satellite View, Google Maps; 2-5: author's images).

Different traffic junctions were chosen to proof whether the developed instrument is applicable for diverse locations on the one hand. On the other hand, these locations are assumed to be either prone to conflicts or to foster safety according to literature. Every cyclist passing our predefined observation area was observed, whereas only cyclists that had been observed having an SCE were assessed via a paper-pencil version of the observation instrument described above (2.1). Filling in the checklist took about one minute. The observers (in total: 2) measured the number of passing cyclists with click counters and documented the number every hour. In advance, observers received a training that comprised a detailed explanation of how to use the instrument and exemplary indications that allow classifying a situation as safety critical for all criteria included. For documenting the cyclists' reaction (*cyclists' behaviour*, s. 2.1) to a SCE 'rebalancing', 'getting off the bike for rebalancing and continuing the trip' were examples for degrading stability without falling (Dozza & Werneke, 2014; Werneke et al., 2015; Schepers &

Klein Wolt, 2012. Observable indications for evasion manoeuvers were determined as spontaneous steering motions to the left or right side (Poulos et al., 2017). Spontaneous decelerations or accelerations are observable for example in cyclists' cadence (pedalling stop or increased pedalling) or by cyclists using the brake (Kolrep-Rometsch et al., 2013; Guo et al., 2010). Observers were instructed that a situation is only to be classified as safety critical if the behaviour shown by the cyclist was necessary to prevent a collision with a person respectively an object, or a fall.

3 RESULTS

3.1 Observation Instrument

For the purpose of proving the concept of the observation instrument that assesses SCEs comprehensively, a validation was carried out based on a sample size of *N* = 1202 observed cyclists passing our observation areas. Using the instrument it was possible to reveal a total of 17 SCEs (1.4 %) at 5 different traffic junctions that would have remained undetected. Applying the selected categories (2), (3), and (4) and corresponding criteria described above (cf. 2.1) it was feasible to document all occurring SCEs.

3.1 Safety Critical Events

Since the present study was a Proof of Concept, this section merely contains descriptive statistics, i.e. frequencies to specify the observed SCEs. From the 17 cyclists that were involved in a SCE, 7 were female and 10 male. The cyclists' age was estimated by the observers and matched to age groups. The majority (*n* = 10) of cyclists was assigned to the age group ranging from 20 to 29 years. Thirteen of them rode a trekking or mountain bike, two rode a city bike and another two rode a racing bike. From the cyclists having a SCE, five wore a helmet.

We documented 24 behaviour patterns (*M* = 1.4) being the cause of the SCEs, which means that a SCE of one person can be composed of more than one causative behaviour patterns (see Table 2).

Table 2. Frequencies of observed behaviour patterns causative for SCEs (N = 17) per observation area and in total.

Behaviour patterns	*Observation areas*					***Total*** *N (%)*
	Separated bike lane	*Bike box*	*Roundabout*	*Through-bike lane*	*Bus stop*	
Undersized distance (e.g. overtaking)	*0*	*3*	*0*	*1*	*0*	***4 (17)***
Tailgating	*0*	*1*	*1*	*0*	*0*	***2 (8)***
Aligning closely	*0*	*1*	*0*	*0*	*0*	***1 (4)***
Blocked cycle path	*0*	*0*	*0*	*2*	*1*	***3 (13)***
Dooring	*0*	*0*	*0*	*0*	*0*	***0 (0)***
Aggressive behaviour - others	*0*	*0*	*0*	*0*	*0*	***0 (0)***
Aggressive cyclist behaviour	*0*	*0*	*0*	*2*	*0*	***2 (8)***
Cross traffic	*2*	*0*	*4*	*0*	*3*	***9 (38)***
Frontal approach	*0*	*0*	*0*	*0*	*0*	***0 (0)***
Miscellaneous	*1*	*1*	*1*	*0*	*0*	***3 (13)***
Total	*3*	*6*	*6*	*5*	*4*	***24 (100)***

Interactions with cross traffic oncoming from either the cyclist’s left or right was the most frequently (38 %) observed behaviour pattern, followed by undersized distances (17 %) kept by the cyclists’ themselves or interactions partners (IPs), for example in overtaking manoeuvers. Neither aggressive behaviour of other road users, nor dooring, nor SCEs in which the IP approached each other frontally could be observed.

All SCEs occurred involving at least one IP (*N* = 19 IPs, *M* = 1.1 IPs/ cyclist with SCE). Cars were identified to be the most frequent IP (37 %). In addition, pedestrians (26 %) and trucks (21 %) were observed comparatively often as an IP in the SCEs as well (cf. Table 3).

Table 3. Number of IPs involved in SCEs (N = 17) per type of observation area.

Interaction Partners	*Observation areas*					
	Separated bike lane	*Bike box*	*Roundabout*	*Through-bike lane*	*Bus stop*	***Total***
Car	*0*	*3*	*2*	*1*	*1*	***7***
Truck	*2*	*0*	*0*	*2*	*0*	***4***
Motorcycle	*0*	*0*	*0*	*0*	*0*	***0***
Other bicycle	*0*	*1*	*0*	*0*	*1*	***2***
Pedestrian	*1*	*0*	*3*	*0*	*1*	***5***
Small e-vehicles[1]	*0*	*0*	*0*	*0*	*0*	***0***
Bus	*0*	*0*	*0*	*0*	*0*	***0***
Tram	*0*	*0*	*0*	*0*	*1*	***1***
Animal	*0*	*0*	*0*	*0*	*0*	***0***
Miscellaneous	*0*	*0*	*0*	*0*	*0*	***0***
Total	*3*	*4*	*5*	*3*	*4*	***19***

[1] Small electrified means of transport (e.g., e-scooter, hoverboard)

As a reaction to the observed SCEs and in order to avoid collisions a total of 23 behaviour patterns (*M* = 1.4 behaviour patterns/ cyclist with SCE) were shown by the cyclists. Evasion manoeuvres (48 %) and spontaneous decelerations (30 %) were performed. We did not observe any SCE that resulted in a loss of stability that entailed a fall off the bicycle. Furthermore, 6 of the cyclists that had a SCE also violated the German Highway Code at least once. In detail, these were right of way violations (*n* = 3), illegally cycling on pedestrian path (*n* = 2), red light running (*n* = 1), and smartphone use while cycling (*n* = 1).

4 DISCUSSION

The aim of this study was to prove the concept of an instrument that assesses SCEs within the scope of a 5-day field observation at 5 different traffic junctions. We therefore found a definition on basis of literature in this field and thereby developed an observational instrument. The instrument was validated on an observed sample of 1202 cyclists of whom 17 were involved in a SCE.

4.1 Instrument and prevalence of SCEs

The results of the feasibility study showed that the constructed categories for a complete objective assessment of SCE are suitable as well. None of the few aspects that fell in the category ‘miscellaneous’ required the inclusion as an extra category. Rather, these were uncertainties on the part of the observers, which indicate that the observer training should be improved at some points. In sum, only small adjustments need to be made to the inquiry material (e.g., this relates to the layout for reasons of clarity and to the gendering which yet is not harmonised).

All SCEs occurred including an interaction with another road user. Even though the data base of SCEs is small, the finding of a greater proportion of interactions with other road users causing SCEs compared to single-bicycle SCEs was also found in previous studies (e.g., Werneke et al., 2015). Most frequently we observed other road users taking an undersized distance when for example overtaking the cyclist, and SCEs that occurred due to other road users crossing the cyclists’ path. Again, the differences for the observed behaviour patterns of the IPs do not show a systematic over-representation of distinct categories, but they suggest a certain direction that is in line with previous findings. Sanders (2015) for example, found a large proportion of SCEs in turning situations, where car drivers crossed the cyclists’ paths; Aldred & Crosweller (2015) state that very close passes were reported frequently by cyclists that experienced SCEs. Due to the traffic junctions we chose exemplarily, certain behaviour patterns were impossible to observe, such as near dooring situations. Furthermore, SCE data showed clearly that cars again are the most common conflict partner (e.g. Poulos et al., 2017). Unsurprisingly, cyclists’ reaction to the SCEs most frequently were evasive manoeuvers. As Zheng et al. (2014) suggest, evasive manoeuvers are the basic distinction between a crash and a near miss. Spontaneous decelerations were the second most common reaction performed by the cyclists. This defensive behaviour is relatable to the cyclists’ distinct vulnerability in comparison to car drivers, for example. Rather than ending up in a severe conflict, cyclists show avoidance behaviour (Hagemeister & Schwamberger, 2007; Kolrep-Rometsch et al., 2013).

Since the focus of the feasibility study was merely to evaluate the observation instrument rather than defining the prevalence and characteristics of SCEs, statements regarding effects of different factors (e.g., infrastructural, sociodemographic, weather etc.) on the occurrence of SCEs cannot be made at this stage. Thus, the findings have limited validity.

4.2 Framework conditions of observation

For the evaluation of the observation instrument, we conducted a five-day feasibility study, whereas we observed cyclists each day at a different traffic junction. In comparison to Kolrep-Rometsch et al. (2013) who also employed an observational study in order to assess SCEs, though focussing concretely on turning situations, the present study collected a wider range of SCEs. Beyond, Kolrep-Rometsch et al. (2013) observed each of their preselected traffic junctions for three hours either in the morning or afternoon. As for important potential SCE influencing factors is not sufficiently attached value, such as time of day, season, weather conditions etc., the developed observational instrument presented here can be seen as an advancement of it considering this lack in the representative main study. Note that the representative main study will be conducted in 3 different German cities at 4 different traffic junctions, employing the developed observation instrument. The 12-week representative observation will be interspersed throughout one year.

From all cyclists passing the observational area, an amount of 1.4 % were observed having at least one SCE. With regard to the season the observation was carried out, November is not a typical month bicycles are used frequently (Nobis, 2019). We assume that cyclists being on the road at this time of year are experienced riders, who in general experience fewer SCEs than less experienced ones (e.g., Aldred & Goodman, 2018; Poulos et al., 2017). Thus, we expect an even larger rate of SCEs when observation is carried out for a time span of 12 weeks throughout one year, given that for a short time span of five days it can be found a rate of 1.4 % yet.

An acquainted problem and a source of error when observation methods are employed is the observer bias. According to Mahtani et al. (2017) observer bias may result from inadequate training in the use of measurement instruments. In order to minimise this bias, we trained all observers in advance by the guidance of a training guideline that we developed.

As mentioned in 1.1, typical of observations is that they do not asses interpersonal factors that are not directly observable, but may deter from cycling as situations are gaged safety critical. Cycling experience, risk perception, and sense of security are just some examples. Adding measures of cyclists' subjective impressions to our observation instrument may contribute to shed more light on the prevalence and occurrence of SCEs and thus can help improve cycling safety. For this reason, a hybrid consisting of observation and subsequent interviews will be realised in the aforementioned representative main study.

4.3 Implications

By now, road safety interventions, such as infrastructural changes are motivated by concrete incident rates (Winters & Branion-Calles, 2017). As soon as representative data regarding the prevalence and characteristics of SCEs is made available using the presented approach, it could be used to encourage the expansion of safer cycling infrastructure. According to Aldred et al. (2017), building more cycling tracks seems to be preferred by cyclists in general in the context of improving cycling safety. Further, results can be used to derive educational campaigns (Guttman, 2015; Nathanil & Adamos, 2013). Also technological advancements could improve of our findings. In the project Rad^{im}Fokus (2020) for example, a warning and assisting system is being developed at the moment that aims at supporting cyclists and car drivers in not only immediate danger situation, but it also gives predictive warnings. Here, the data on which base warning messages are calculated could be enriched with the knowledge gained from our results.

5 CONCLUSIONS

This paper presented the Proof of Concept of a novelly developed observation instrument that aims at assessing cyclists' SCE by integrating previous approaches (i.e. SCE definitions and SCE-indicating criteria). Results of our field observation employing the instrument are promising. The development and evaluation of the instrument plays an important role, as it forms the basis for a large project ('DRadEsel', 2019), which aims at shedding light on the dark-field of cyclists' SCEs and thereby give detailed information on the prevalence and characteristics of underreported SCEs to improve cycling safety.

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