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School of Transportation Sciences

Master of Transportation Sciences

Master's thesis

Cycling behaviour of children

Corinna Winter

Thesis presented in fulfillment of the requirements for the degree of Master of Transportation Sciences

SUPERVISOR :
Prof. dr. Ariane CUENEN

MENTOR :
De heer Roeland PAUL

CO-SUPERVISOR :
Prof. dr. Davy JANSSENS

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Cycling Behaviour Of Children

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Abstract

Introduction: In Germany 10-to until 15-year-olds register among the highest absolute numbers of injuries due to cycling crashes. Boys have a particularly high proportion with 72%, compared to other age groups. In Belgium, the number of cycling crashes peaks for the first time around the age of ten and boys account for 64% of the injured cyclists. The relatively high numbers of cycling crashes of children and the disproportionately high share of boys are a relevant issue in road safety. The question arises which role cycling behaviour plays.
Objective: The objective of this study is to analyse the cycling behaviour of 10-to 15-year-old boys compared to girls in Germany and Belgium. This includes violations, errors, and positive behaviours according to the Cycling Behaviour Questionnaire (CBQ).
Method: For this study, a total of 93 children from Germany and Belgium answered a questionnaire on cycling habits, crashes, infringements, cycling behaviours and personality traits.
Results: The outcomes of this study indicate German boys show a riskier cycling behaviour than girls, while girls perform more protective behaviours. Errors and violations were significantly positively correlated to crashes, and only boys had been severely injured. However, personality traits were not found to play significant role in the frequency of infringement of traffic rules. In contrast, for the Belgian sample, the CBQ did not show gender specific cycling behaviour. Comparing cyclists from both countries, significant differences for several CBQ items were found. German children committed more errors and violations, while Belgian children showed higher values for positive behaviours, and a lower share had been involved in crashes. These findings suggest that German children are more reckless and have a poorer risk perception.
Conclusion: The results of this study indicate that in Germany boys perform more risky cycling behaviour and are injured more severely than girls, whereas in Belgium no significant gender differences were observed. In view of the high number of injured children in cycling crashes it is necessary to improve training programmes and consider gender specific behaviour in Germany.

Keywords: Children; Cycling Behaviour Questionnaire, Germany, Belgium

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1. Introduction

1.1. Cyclists injured and killed in Germany

With 3,78 road traffic deaths per 100.000 inhabitants, Germany is one of the European countries with the lowest road crash fatality rates (WHO, 2021). The long-term trend between 2000 and 2020 shows a decreasing number of road deaths, especially for car users, pedestrians, and moped riders with reduction of 73%, 62%, and 66% respectively (ITF, 2021a). Nevertheless, for cyclists the reduction of road deaths was lower, with only 35% during the same time interval (ITF, 2021a). Moreover, from 2010 to 2020, the number of cyclists killed on German roads has even risen again by 11,8%, while during the same period the overall number of road deaths fell by 25,5% (ITF, 2021a). It should be noted that due to the COVID-19 pandemic and lockdowns, in 2020 fewer fatalities were reported than in previous years. Therefore, when analysing the time interval 2010 to 2019, the percentual increase in cyclists' facilities is even higher with 16,8% and overall fatalities only fell by 16.5% (ITF, 2021a).

The increasing popularity of cycling may partly account for the level of cyclists' fatalities, among other factors such as insufficient infrastructure (European Commission, 2021). This trend is consistent with the data from Germany's Cycling Monitor 2021, where 25% of the interviewees answered they were using their bike more frequently than prior to the pandemic and 41% indicated that they were planning to use to do so in the future (BMDV, 2021). Young people of 14 to 29 years use bicycles or speed pedelecs most frequently, 45% of them daily or several times per week (BMDV, 2021). However, also 30% of the interviewees aged between 14 and 69 said they felt rather not safe when cycling in road traffic and 7% felt not safe at all. The most frequent reasons were too much traffic (64%), reckless car drivers (62%), not enough separate cycle tracks (57%), and cars driving too fast (56%). At the same time, more than 80% fully or partially agreed they were always following the road traffic rules as a cyclist, and 45% were using a helmet most of the time. For the age group of 14- to 19-year-olds, only 37% indicated that they were using a helmet always or most of the time, slightly less than other age groups.

Analysing cycling accident statistics, it is striking boys between 10 and until 15 years were among the age groups with the highest injuries in Germany in 2020, as shown in Figure 1. In 2020, 4.788 male cyclists in this age group were killed or injured, while 1.903 female cyclists were reported for the same age group (Statistisches Bundesamt, 2021). It should be noted that most of these boys were slightly wounded (4.192), but also considering this specification, in comparison significantly fewer girls (1.693) were slightly wounded (Statistisches Bundesamt, 2021). This pattern can also be observed in the data from previous years, revealing that boys from 10 to until 15 are more than twice as likely to be injured or killed in a cycling accident (Statistisches Bundesamt, 2021). While also other groups, particularly between 50 and 60, and 75 and older, show high risk profiles, the gender difference is most remarkable for teenagers.

According to a representative study on mobility behaviour in Germany, 21% of the males between 11 and 13 years used the bicycle as the main mode of transport for their trips and 19% of the females (BMDV, 2017). For 14- to 17-year-olds the numbers are similar, with 23% of the boys and 18% of the girls using the bike as the main mode of transport for their trips (BMDV, 2017). Therefore, although the cycling use is slightly higher for males than for females, this does not explain that 72% (Statistisches Bundesamt, 2021) of the killed and injured cyclists in the age group of 10 to until 15 are males.

Figure 1. Dead and injured cyclists in Germany in 2020 (own creation based on (Statistisches Bundesamt, 2021, p. 30))

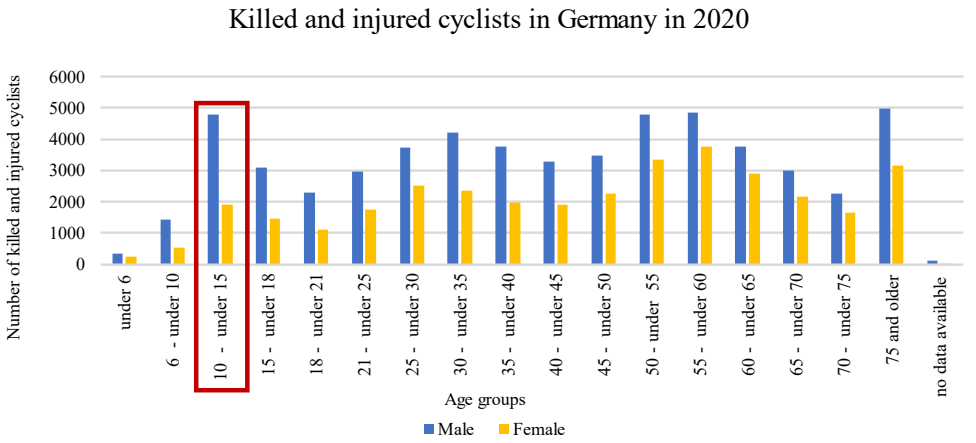

Table 1 shows the number of injured cyclists Germany both in total and relative terms, and noticeably 10- to until 15-year-olds show among the highest absolute numbers of injured, with a strong distinction compared to the adjacent age groups. Boys between 6 and until 15 years report much more injuries (72%) than their female peers, however in absolute numbers 10- to until 15-year-olds have among the highest number of incidents with injuries, together with persons older than 75.

Table 1. Injured cyclists in Germany in 2020 (own creation based on (Statistisches Bundesamt, 2021, p. 30))

	Male	**Female**	**Total**	**% Male**	**% Female**
Under 6	337	251	588	57%	43%
6 – under 10	1.420	540	1.960	72%	28%
10 – under 15	4.780	1.902	6.682	72%	28%
15 – under 18	3.045	1.469	4.514	67%	33%
18 – under 21	2.238	1.105	3.343	67%	33%
21 – under 25	2.898	1.737	4.635	63%	37%
25 – under 30	3.695	2.500	6.195	60%	40%
30 – under 35	4.170	2.347	6.517	64%	36%
35 – under 40	3.709	1.972	5.681	65%	35%
40 – under 45	3.217	1.912	5.129	63%	37%
45 – under 50	3.439	2.255	5.694	60%	40%
50 – under 55	4.714	3.350	8.064	58%	42%
55 – under 60	4.728	3.750	8.478	56%	44%
60 – under 65	3.678	2.893	6.571	56%	44%
65 – under 70	2.933	2.164	5.097	58%	42%
70 – under 75	2.218	1.630	3.848	58%	42%
75 and older	4.781	3.100	7.881	61%	39%
No data available	105	33	138	76%	24%
Total	56.105	34.910	91.015	62%	38%

Germany's Federal Statistical Office is not only recording crashes, but also misbehaviours leading to cycling crashes. Among all age groups, the most common misbehaviour was incorrect road use (17%), thus driving in the wrong direction of travel, or using forbitten parts of the street, followed by inappropriate speed (10%) (Statistisches Bundesamt, 2021). For cyclists until 15 years, likewise incorrect road use was the most common misbehaviour with 18%, followed by misbehaviour when turning, reversing, driving in and starting up with 17%. The latter is particularly high in this age group, compared to all ages (8%). This indicates that younger cyclists show more incorrect behaviour at intersections or when changing direction and entering flowing traffic. Another common misbehaviour of persons younger than 15 is not respecting the right of way or priority, with 10% and inappropriate speed with 8%. The statistics are including a high share of other misbehaviours which is not further specified (39% for all age groups and 38% for until 15-year-olds).

In 2020, in 69% of the cycling accidents with personal injury another road user was involved. Thereof 71,9% were cars, making them the most frequent other party in cycling accidents, while only 11,3% were other cyclists and 6,6% pedestrians (Statistisches Bundesamt, 2021, p. 8). In almost half of the cycling accidents, cyclists were considered the main responsible, however, when cars were involved in the accident, cyclists were only regarded as main responsible in 24,8% of the cases (Statistisches Bundesamt, 2021). On the other hand, in accidents with pedestrians, cyclists were the originator in 56,7% of the incidents (Statistisches Bundesamt, 2021).

1.2. Cyclists injured and killed in Belgium

Like Germany, Belgium has relatively few road traffic deaths, with a ratio of 4,3 per 100.000 inhabitants in 2020 (ITF, 2021b). Also here the long-term trend shows a decrease in road fatalities, with a reduction of 66,1% between 2000 and 2020. However, comparing the decade from 2010 to 2020, it can be observed that cyclists were the only road users reporting an increase in fatalities amounting to 15% (ITF, 2021b).

Official statistics by the Belgian VIAS Institute show that in 2021 62% of the total 10.330 cyclist causalities were men, of the fatalities even 75% (VIAS Institute, 2022). As can be seen in Table 2, showing the number of injured cyclists in Belgium for 2021 both in total and relative terms, in all age groups males report more injuries than their female peers.

Nieuwkamp and Schoeters (2018) state the number of cycling crashes in Belgium peaks a first time around the age of ten. Accidents with motorised vehicles account for the largest share of incidents under the age of 20 (Nieuwkamp & Schoeters, 2018). As shown in Table 2 in the youngest age groups the share of males is slightly higher than in all other age groups with data available. Thus, also in Belgium statistics reveal a that the young male cyclists are more frequently injured or killed in cycling crashes.

Table 2. Injured cyclists in Belgium in 2021 (own creation based on (VIAS Institute, 2022))

	Male	**Female**	**Total**	**% Male**	**% Female**
0 -17	1.061	587	1.648	64%	36%
18 - 24	784	426	1.210	65%	35%
25 - 34	911	602	1.513	60%	40%
35 - 54	1.754	1.050	2.804	63%	37%
55 - 64	866	586	1.452	60%	40%
65+	907	568	1.475	61%	39%
no data available	58	11	69	84%	16%
Total	6.341	3.830	10.171	62%	38%

1.3. Cyclists injured and killed in European countries

Comparing data from other European countries, it can be observed that cyclists are the only road users for which the fatalities have not declined in the last decade (European Commission, 2021). The relative proportion of serious injuries in the EU 27 has slightly increased, from 7% in 2010 to 9% in 2019 (European Commission, 2021). The Netherlands (26%), Denmark (16%), Belgium (14%), and Germany (13%) were the countries with the highest cyclist fatality rates in the context of road fatalities, although this is likely to be related to these countries having a large cycling population (European Commission, 2021).

Male cyclists having a higher proportion in fatalities can also be observed as a pattern in other European countries, and for the EU 27 their share amounts to 82% of the cyclists killed. The facts and figures by the European Road Safety Observatory on cyclists in 2021 do not provide data combining age and gender for injured or killed cyclists, but the available information on age demonstrates the number of cyclists fatalities increases for 0 to 4 year olds and 15 to 19 year olds, although it is highest for 75 to 79 year olds (European Commission, 2021).

1.4. Cycling behaviour

Although infrastructure plays an important role in cyclists' accident risk (Alrutz, Bohle, & Maier, 2015), statistics reveal that cycling behaviour frequently contributes to crashes (Statistisches Bundesamt, 2021). In view of the observed differences among age groups and gender with respect to cycling crashes, occurring under similar infrastructure conditions, this thesis focuses on cycling behaviour of children, in particular of boys.

Traffic research has identified demographics (Martínez-Ruiz, et al., 2014), skills (Briem, Radeborg, Salo, & Bengtsson, 2004), habits (Useche, Montoro, Tomas, & Cendales, 2018), and personality traits (Useche, et al., 2022) as important explanatory factors for cycling behaviour, which will be examined in the following section.

Useche, Montoro, Tomas and Cendales (2018) underline that road user behaviour is the most important safety factor. In their study to validate the self-reported Cycling Behaviour Questionnaire (CBQ) they distinguish three types of cycling behaviours: violations, errors, and positive behaviours. Violations are defined as intentional deviations from traffic rules, and according to the authors they originate 70% of the severe traffic injuries in Northern America (Useche, Montoro, Tomas, & Cendales, 2018). The motives for violating traffic rules are road safety attitudes, knowledge of traffic rules, control, and sanctions, which are influenced by demographic factors such as gender and age (Useche, Montoro, Tomas, & Cendales, 2018). In contrast, errors are not intentional, but an action which failed to obtain the expected outcome, possibly leading to a crash or near-crash (Useche, Montoro, Tomas, & Cendales, 2018). They are related to inadequate risk perception or skills, and according to the authors in particular young drivers have been found to make errors previous to serious crashes. On the other hand, positive behaviours are protective habits and actions which help to mitigate risks, for example through prudent speed or safe distance (Useche, Montoro, Tomas, & Cendales, 2018). This behavioural aspect is often neglected in empirical studies, but relevant to understand how cyclists' safety can be strengthened (Useche, Montoro, Tomas, & Cendales, 2018). Useche et al. (2018) found that gender impacted the number of traffic violations, such as cycling under alcohol, going against the direction of traffic, zigzagging between vehicles, handling obstructive objects, speeding, or crossing red lights, with males showing significantly more violations than females. Furthermore, female cyclists showed more positive driving behaviours, employing more passive-safety elements, and perceived more situations as hazardous than men. In general, cyclists older than 29 were found to commit fewer errors and violations, while having more positive behaviours than younger age groups. These findings are consistent with the analysed statistics, showing that younger cyclists are killed or injured more frequently than mid-aged cyclists, and the higher number of violations may provide an explanation why males expose a higher risk profile.

Stevens, Plumert, Cremer and Kearney (2012) studied preadolescent temperament and risky behaviour based on a cycling simulator. Stevens et al. (2012) state that the findings from various studies suggest that children exhibiting lower levels of inhibitory control and higher levels of aggression are more susceptible to injury. This susceptibility

may be attributed to their inclination towards engaging in precarious activities (Stevens, Plumert, Cremer, & Kearney, 2012). In line with this previous research, their study revealed that notably 10-year-old boys with higher levels of aggression showed riskier cycling behaviour. The authors furthermore found that children at the age of 10, compared to 12-year-olds, and girls entered the intersection less timely, indicating that age, gender, and temperament seem to play a role in cycling behaviour (Stevens, Plumert, Cremer, & Kearney, 2012).

A study by Feenstra, Ruiter and Kok (2010) on the social-cognitive correlates of risky cycling behaviours of adolescents analyses why teenagers show more risky traffic behaviours. The authors state this might correspond with a higher degree of independence (i.e. less parental supervision), hormonal changes inducing a higher susceptibility to social approval (i.e. bravery to impress peers), and testing of limits (Feenstra, Ruiter, & Kok, 2010). It should be noted adolescents perceive themselves to be at a higher risk than adults, but in contrast to generally more risk adverse adults, teenagers may prioritise short term advantages of situation and take calculated risks (Reyna & Farley, 2006). Feenstra et al. (2010) measured risky adolescent behaviour through a self-report questionnaire, and found that gender, self-efficacy, risk comparison, attitude toward alcohol use in traffic, personal norm towards one's own safety, personal norm others' safety, past accident involvement, near accident involvement, perceived risk taking, and intention of risky behaviour are determinants of cycling behaviour (Feenstra, Ruiter, & Kok, 2010).

Feenstra, Ruiter, Schepers and Peters (2011), also employed a self-report questionnaire, the ACBQ (Adolescent Cycling Behaviour Questionnaire), to measure risky adolescent cycling behaviour, which distinguishes between errors and violations. They found no difference in the errors and common violations comparing participants under and over 15 years, which appear to be committed by all adolescents between 13 and 18 equally. However, older participants showed significantly more exceptional violations such as using cell phone, getting pulled or pushed by a moped rider, or cycling under the influence of drugs. The findings furthermore indicate that gender plays a role in cycling behaviour. The authors report that boys make more errors (e.g., no seeing other vehicles, assessing speed incorrectly), and violate traffic rules (e.g., riding on the sidewalk, not signalling) more frequently than girls (Feenstra H. , Ruiter, Schepers, & Peters, 2011). The motives for these behaviours are not captured through the questionnaire.

1.4.1. Demographics

In line with the cited studies on cycling behaviour, Martinez-Ruiz et al. (2014) identified age and gender as important demographic factors for the risk of involvement in a cycling crash. They examined exposure rates to crashes and crash ratios for cycling crashes in Spain from 1993 to 2009, and used these variables to calculate crash rates which are adjusted to exposure (Martínez-Ruiz, et al., 2014). Their study included cyclists from 5 to 79 years, and the highest unadjusted crash rates, thus cyclists involved in crashes in relation to the total population for the respective age group, were found for males from 10 to 19 years. The values for females were much lower than those of their male peers in all age groups, but also younger female cyclists from 10 to 19 years showed the highest crash rates with among all females. When adjusting the crash rates by considering the exposure rates, thus only the cyclists not responsible for the crash in relation to the total population, a different pattern was observed. The adjusted crash rate ratios showed only small differences between males and females, however, the largest differences were recorded for young cyclists (6 to 14), showing higher values for boys. The authors formulate the hypothesis that this might be due to less experience, insufficient knowledge of traffic rules and lower risk perception. Consistent with this assumption on risk perception, they found that excess risk was higher for young cyclists not wearing a helmet (Martínez-Ruiz, et al., 2014).

Briem, Radeborg, Salo, and Bengtsson (2004), provide further evidence for relevance of gender and age in cycling behaviour. In a study on developmental aspects of children's behaviour and cycling safety with Swedish data, they showed the rate of cycling accidents increased steadily until children were 12 to 13 years old, and boys were twice as likely to be involved in a serious cycling accident (Briem, Radeborg, Salo, & Bengtsson, 2004). Although the higher numbers of boys' cycling accidents might be related to their higher level of activity, the authors state the phenomenon is likely also shaped by psychological factors associated to the cognitive development and risk attitude. In their study with children from 8 to 12 in a simulated traffic environment, they found that generally boys cycled considerably faster and made more speed related mistakes, while younger girls missed more signals due to a lapse of attention.

Briem et al. (2004) attribute the higher risk taking of older children to a higher self-confidence with more cycling experience and capacity, while the concern about consequences diminishes. The increasing importance of social desirability in adolescence with brave and spectacular actions may further reinforce risky behaviour (Briem, Radeborg, Salo, & Bengtsson, 2004).

1.4.2. Cycling skills

According to Briem et al. (2004), cycling requires both motor skills (pedalling, balancing, navigating, braking) and cognitive capacities, such as concentration, awareness, reasoning, planning, and decision making. While children could be expected to improve their cycling skills as they get older, due to better cognitive and motor capacity, this is not supported by accident data. The authors therefore assume that older children show more risky behaviour by driving faster (Briem, Radeborg, Salo, & Bengtsson, 2004).

In a recent systematic review on the development of bicycling skills in children, Zeuwts, Deconinck, Vansteenkiste, Cardon, and Lenoir (2020) define cycling as a combined skill, which requires motor skills, perceptual-motor skills (e.g., for the detection of hazards and reasoning), knowledge of traffic rules, and attitudes. In their study they examine how age influences this skillset consisting of four components (Zeuwts, Deconinck, Vansteenkiste, Cardon, & Lenoir, 2020). With respect to motor skills, they report that an improvement can be observed with increasing age. While some studies indicate an adequate motor development at the age of ten, others state that even at the age of twelve the motor control was still insufficient (Zeuwts, Deconinck, Vansteenkiste, Cardon, & Lenoir, 2020). Concerning perpetual-motor skills, they state that processing speed and reaction times improve as children get older, leading to better comprehension of complex scenarios. Furthermore, Zeuwts et al. (2020) identified young cyclists having a reduced knowledge of the road code. With regards to attitude, they found increasing age tends to lead to a deterioration. They attribute this change partially to the fact that the socio-emotional centre in the brain becomes more sensitive during adolescence, making sensation seeking and riskier behaviour more appealing.

1.4.3. Personality traits

Useche et al. (2022) studied the influence of personality traits on risky cycling behaviours. Personality traits were measured under the Big Five paradigm, analysing openness, conscientiousness, extraversion, agreeableness, and neuroticism (Useche, et al., 2022). Cycling behaviour was examined with the Cycling Behaviour Questionnaire, considering violations, errors, and positive behaviour. The authors found errors and violations to be negatively correlated to conscientiousness and agreeableness, and in addition errors were also negatively correlated to openness. In contrast, errors and violations were positively correlated to extraversion and neuroticism. Consistently, positive behaviours were positively correlated to conscientiousness, agreeableness, and openness, but negatively correlated with neuroticism. They furthermore detected that only the personality traits of openness and agreeableness were significantly correlated to self-reported crashes: openness increased the likelihood of crashes, while agreeableness was related to lower crash rates. In line with previous research, males showed a higher likeliness of crashes. Useche et al. (2022) therefore derive that personality traits can be an important factor to predict the involvement in crashes, as well as gender, cycling intensity and behaviour.

Further evidence for the relevance of psychological determinants regarding risky cycling behaviour is provided by Twisk, Commandeur, Vlakveld, Shope, and Kok (2015). The authors analysed the relationship of psychological determinants, risky behaviour, and road crashes of 12- to 16-year-old pedestrians and cyclists based on a questionnaire and found that risky behaviours such as errors, dangerous play and lack of protective behaviour predicted crashes for 12- to 13-year-olds, while in the case of 14- to 16-year-olds only errors were predictors for crashes. Risky behaviour in turn could be predicted from the psychological determinants such as opinions about traffic rules, carelessness, opinions of alcohol, competencies in comparison to those of others, feeling responsible for actions and hazard awareness (Twisk, Commandeur, Vlakveld, Shope, & Kok, 2015).

2. Objectives and key research questions

In line with the introduction, the main objective of the study is understanding why boys between 10 and 15 years are especially prone to being injured or killed in cycling crashes. The goal is therefore to analyse the cycling behaviour of boys compared to their female peers in the target age group, including violations, errors, and positive behaviours; how this relates to the personality, and if the behaviour differs between German and Belgian cyclists. The results of the study may serve as an input for intervention strategies to reduce the risk exposure of boys within the target age.

The key research question of the study is: Does the cycling behaviour (errors, violations, positive behaviours) of 10- to 15-year-old males and females differ?

To understand factors that might affect the behaviours, the following sub-questions are addressed in the thesis:
1. Which are the reported causes of crashes of 10- to 15-year-old cyclists?
2. Does cycling behaviour in Germany differ according to personality traits?
3. How does cycling behaviour of 10- to 15-year-olds compare in Germany and Belgium?

3. Method

3.1. Data collection

The data to analyse the research questions were gathered through an online survey on self-reported behaviour in Germany, and through a questionnaire on self-reported behaviour in Belgium, both created with the online tool Qualtrics, allowing to participate both from a computer or a mobile device.

3.1.1. Germany

The survey was designed in German and consisted of four sections. In the first section, demographic and individual cycling habit related questions were asked, such as age, gender, postal code, school type, cycling frequency and preferences.

The second section focussed on self-reported crashes and infringements, namely the frequency and motives for violations of traffic rules, involvement in crashes in the last 3 years, role (as victim or initiator), injuries and causes of the crash, if applicable. The definitions of injuries (severely or slightly) and causes of the crash were taken from the categories recorded by the German Federal Statistical Office (Statistisches Bundesamt, 2021), to allow for comparability with official statistics. However, when the cause of crash was due to human errors, in addition to the categories used by the German Federal Statistical Office, the differentiation of own behaviour and behaviour of others was made in the multiple-choice answers, to obtain a better understanding of the responsibility of the crash.

The third section consisted mainly of the Cycling Behaviour Questionnaire (CBQ), according to Useche, Montoro, Tomas and Cendales (2018), and questions regarding cycling skills, safety perception and reasons for not feeling safe in road traffic if applicable. The questions and answer possibilities regarding safety perception and the lack of feeling safe when cycling were taken from the Cycling Monitor Germany, which is elaborated annually with support of the German Federal Ministry for Digital and Transport (BMDV) and available both in German and English (BMDV, 2021). The CBQ is a validated questionnaire developed by Useche et al. (2018) and examines risky behaviours (deliberate in form of violations or undeliberate in form of errors) and positive behaviours, thus including a holistic set of behaviours concerning cycling safety. The questionnaire consists of 29 items with a 5-point Likert scale going from never (=0) to always (=4), and has been tested in English, French, Spanish, and Dutch. Since no version of the CBQ in German was available, the author translated the questionnaire from English to German and cross-checked with the versions in French and Dutch.

The fourth section consisted of questions regarding personality traits under the Big Five OCEAN approach, namely neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness (Lang, John, Lüdtke, Schupp,

& Wagner, 2011). The questions were taken from the Short Big Five Inventory (BSF-I), according to Lang, John, Lüdtke, Schupp and Wagner (Lang, John, Lüdtke, Schupp, & Wagner, 2011), which is available in English and German. Gerlitz and Schupp (2005) developed this instrument to measure the Big Five personality factors in large surveys, measuring each of the five personality factors with 3 items on a 7-point Likert scale from 1 (strongly disagree) to 7 (strongly agree).

3.1.2. Belgium

The questionnaire was designed in Dutch and concerned demographics, cycling habits, skills, crashes, and cycling behaviour (see Appendix B.), equivalent to the first, second and third section of the survey used in Germany. The translated version of the CBQ in Dutch was taken from Useche, Philippot, Ampe, Llamazares and Geus (2021). Most of the questions asked are very similar to the described online survey in Germany, as can be seen in the appendix, and thus allow for good comparability.

3.2. Participants

Both in Germany and Belgium the study was targeted at boys and girls between 10 and 15, since this age group and in particular males reported among the highest numbers of deaths and injured cyclists in Germany (Statistisches Bundesamt, 2021) and also in Belgium the number of cycling crashes peaks for the first time around the age of ten (Nieuwkamp & Schoeters, 2018). Similar to Germany, the statistics indicate that young male cyclists in Belgium are more frequently killed or injured, with 64% of the casualties (VIAS Institute, 2022), making this group highly relevant to study their cycling behaviour.

3.2.1. Germany

In Germany the invitation to participate in the survey was promoted through flyers with QR codes located close to schools, traffic training sites and bicycle racks in Berlin at more than 30 locations and personal networks of the author asking parents to support the participation of their children. The author furthermore contacted environmental and social organisations with youth sections (BUND Jugend, NaturFreunde Jugend, Johanniter), and student city councils, which are representatives of all the schools of a particular city. The student city councils of Wiesbaden, Frankfurt, Darmstadt, Braunschweig, Oldenburg, Wiesbaden, Hildesheim, Emden, Kassel, Leipzig, Gießen, Halle, Dresden, Wolfsburg, and Chemnitz were asked to participate, share the flyer at schools and social media, and to include the call in their newsletters. To enhance the participation, 5 Amazon vouchers worth 20 euros were raffled among the participants.

3.2.2. Belgium

In Belgium the participants were recruited via e-mails to employees of Hasselt University, at schools and via Facebook and invited to come to Hasselt University to fill out the questionnaire.

3.3. Procedure

Participants were informed their responses were anonymous and only used for research. It was emphasised that all questions should be answered honestly and that no wrong or right answers existed. Participants were required to indicate their voluntary informed consent before proceeding with the survey.

3.3.1. Germany

In Germany data were collected from 27th of February to 17th of April 2023. If respondents indicated that they were younger than 10 or older than 15, they were directed to the end of the survey, to avoid participation out of the targeted age group. All questions were mandatory, except for the postal code, which some children might not know already. At the end of the survey participants had the possibility to click on a dedicated link to participate in the raffle for the Amazon vouchers. This step was separated from the survey to ensure the participants' privacy, without connecting the answers to the e-mail addresses required for the raffle.

3.3.2. Belgium

In Belgium data were collected directly at Hasselt University, where children from 11 to 15 years filled out the questionnaire from 29th of March to 14th of April 2023.

3.4. Data-analysis

For both samples basic descriptive analyses such as means, standard deviations and percentages were performed to understand demographic features, habits, skills, safety perception, crash frequency, the items of the Cycling Behaviour Questionnaire, and also personality traits in the case of the German sample. These descriptives were calculated for the totals of the German and the Belgian samples, but also differentiating gender for the respective samples. Due to the rather small size of the samples, Fisher's Exact Tests at p-values less than or equal to 0,05 were used to test the relationship between gender and cycling frequency, protective behaviour, violation of traffic rules, crash involvement, injuries, cycling skills, CBQ items, and personality traits.

Useche et al. (2018) formed three dimensions of cycling behaviours in their study, namely violations for items 1 to 8, errors for items 9 to 23, and positive behaviours for items 24 to 29. To test whether the results allowed for grouping of the results according to these dimensions, the internal consistency was verified by calculating Cronbach's alpha, with a criterion of $\alpha > 0,7$. Lang, John, Lüdtke, Schupp and Wagner (2011) also grouped the items of the Short Big Five Inventory (BSF-I) to dimensions, namely 1 to 3 for neuroticism, 4 to 6 for extraversion, 7 to 9 for openness, 10 to 12 for agreeableness, and 13 to 15 for consciousness. Also here the internal consistency was checked with the criterion of Cronbach's alpha $\alpha > 0,7$. For both samples a Spearman's bivariate correlation analysis was performed to identify associations between the main study variables, considering only dimensions that were compliant with a Cronbach's alpha of $\alpha > 0,7$.

To compare both samples they were merged, and basic descriptive analyses were performed. Furthermore, a Mann-Whitney-U-Test was performed to analyse whether there were significant differences between the two samples with respect to the CBQ. All analyses were performed with IBM SPSS Statistics, version 28.0.

3.4.1. Germany

A total of 66 participants answered the survey, thereof 3 did not answer any questions and only agreed to participate. Another 22 were 16 or older and therefore directed towards the end of the survey after responding to the first question regarding their age. Thus, 41 children from 10 to 15 years filled out the survey. The response rate was 92,7%, as 3 participants did not fully answer the online survey. Therefore, a sample consisting of 38 participants who completed the survey was considered for the analysis.

3.4.2. Belgium

A total of 55 participants from 11 to 15 years filled out the online survey and were considered for the analysis. The response rate was 100%, as participants were asked to fill out the survey directly at Hasselt University.

4. Results

4.1. Germany

4.1.1. Demographics and cycling habits

In total 38 children from 10 to 15 years answered the online survey. The sample comprised 19 boys (50,0%), 17 girls (44,7%) and 2 diverse (5,3%) with a mean age of 12,82 years (SD=2,002). Given that primary school usually ends at the age of 10 in Germany, only 2,6% of the respondents attended this type of school and 97,4% secondary school. More than 84,2% of the participants cycle weekly, thereof 57,9% even daily. Thus, most of the children used their bike very regularly and it can therefore be assumed they are relatively experienced cyclists. A Fisher's Exact Test did not reveal any significant differences with respect to gender and cycling frequency.

Regarding company, 52,6% of the participants indicated they cycle mostly alone, followed by 39,5% who mostly cycle with friends. Only 7,9% answered they cycle mostly with their family. Concerning the reason for using the bike multiple choices were allowed, and 68,4% responded they used it to go to school, 55,3% for leisure activities, 31,6% to go to friends and family, and only 5,3% without a specific purpose, but because they liked cycling. Thus, the children mostly cycle due to a derived demand. The vast majority (94,7%) of the survey participants used a standard bike, and only 7,9 % an e-bike, indicating that e-bikes are not very common among children. More than half (52,6%) of the children answered they used a helmet, whereas 39,5% indicated they didn't use any protective equipment. No significant differences were found with respect to gender.

4.1.2. Crashes and violations

Concerning to traffic rules, 26,3% of the children indicated they never violated traffic rules (question 10), 39,5% seldomly, 21,1% sometimes and 13,2% even regularly. A Fisher's exact test did not show any significant differences among males and females. Being asked for the reasons of the traffic violation with multiple options, 34,2% indicated time constraints, 28,9% carelessness, 18,4% distraction, and only 5,3% (all males) to impress others. Another 13,2% answered they violated traffic rules due to other reasons, such as safety concerns (e.g., cycling on the pedestrian walk due to lack of road space for cyclists), unintentional violations, fun (e.g., using only the back wheel) or considering that nobody is put in danger due to the violation.

Most of the participants answered they had not been involved in a cycling crash in the last 3 years (68,4%), 23,7% were involved once, 5,3% twice and 2,6% even 3 or more times. A Fisher's exact test did not find any significant differences in crash frequency of boys and girls. Interestingly, of the 31,58% involved in crashes, 41,7% answered they had been both victim and initiator, 25% only initiator and 33,3% victim. Of the participants who were involved in a cycling crash (n=12), 58,3% suffered no injuries, 25% slight injuries and 16,7% even severe injuries with stationary hospital treatment. A Fishers exact test indicated that the injuries differ significantly between boys and girls (p=0,033), and the data shows that only boys were severely injured (n=2), while only girls were slightly injured (n=3).

The most common cause of the crash was incorrect road use of the cyclists themselves (4; 33,33%, thereof 2 boys, 1 girl and 1 diverse), followed by incorrect road use of others (3; 25%), overtaking errors of others (3; 25%), and obstacles (3; 25%). Other causes selected were poor driving ability of themselves or others (indicated only by males), inappropriate speed of themselves or others, errors when driving side by side of themselves or others, not respecting the right of way of themselves or others, wrong behaviour of pedestrians, road conditions, and weather conditions.

4.1.3. Cycling skills and safety perception

Analysing cycling skills, 76,3% of the participants considered their cycling skills good or very good, 21,1% neural, and only 2,6% very bad. A Fisher's exact test did not reveal any significant differences with respect to cycling skills and gender. With regards to the safety perception, 26,3% felt very safe, 57,9% mostly safe, 10,5% rather not and 5,3% not at all. Those children who indicated that they felt rather not safe or not at all, were asked for the reasons allowing multiple choices. The most common replies were that they felt (rather) unsafe due to reckless car drivers (5; 83,3%), not enough separate cycle tracks (4; 66,7%), cars driving too fast (4; 66,7%), cars stopping on cycle tracks (4; 66,7%), too much traffic (3; 50%) and cycle tracks in poor condition (3; 50%).

4.1.4. Cycling Behaviour Questionnaire

For the German sample, the reliability of the three dimensions of the CBQ was high, with Cronbach's Alpha $\alpha >$ 0,857 for violations, $\alpha > 0{,}925$ for errors, and $\alpha > 0{,}887$ for positive behaviours. Therefore, and given that the questions are based on the same scale, the dimensions of violations, errors, and positive behaviours were calculated as new variables based on the means per participant. However, except for openness, the personality trait dimensions did not comply with the criterion of Cronbach's Alpha and were therefore not considered further in the analysis (neuroticism: $\alpha > 0{,}63$; extraversion: $\alpha > 0{,}547$; openness: $\alpha > 0{,}845$; agreeableness $\alpha > 0{,}339$; consciousness: $\alpha > 0{,}404$).

Spearman's bivariate correlation analysis shown in Table 3 indicates significant positive correlations for gender with the created variables regarding violations and errors at 0,05 level, and a significant negative correlation for positive behaviours. Violations are also positively correlated at the 0,01 level with errors, at the 0,05 level with crashes and age, and negatively correlated to positive behaviours. Furthermore, errors are significantly negatively correlated to positive behaviours, and positively correlated to crashes.

Table 3. Bivariate Spearman's rho correlations among study variables

Study Variable		Mean	SD	1	2	3	4	5	6	7
1	Age	12,87	2,00	--						
2	Gender	1,61	0,59	0,049	--					
3	Cycling frequency	1,66	0,94	0,000	-0,135	--				
4	Violations	0,72	0,70	0,392*	0,364*	0,044	--			
5	Errors	0,64	0,63	0,203	0,404*	0,193	0,767**	--		
6	Positive behaviours	2,40	1,04	-0,059	-0,346*	0,201	-0,345*	-0,375*	--	
7	Crashes (3 years)	1,42	0,72	-0,194	0,162	-0,186	0,384*	0,382*	-0,298	--

Notes: * Correlation is significant at the 0,05 level (2-tailed), ** Correlation is significant at the 0,01 level (2-tailed).

The results of the CBQ for the online survey in Germany are shown in Table 4. The mean values for males are higher than the mean values for females in all items concerning the dimensions of violations and errors, indicating boys have a riskier cycling behaviour than girls. In line with these results, the mean values of girls are higher for all items regarding protective behaviour. However, a Fisher's exact test indicated significant differences only for the item 14 (p=0,031), braking very abruptly on a slippery surface, and item 26 (p=0,040), keeping a safe distance. With respect to item 14, 94,1% of the girls answered they never or rarely broke abruptly on slippery surface, while 63,2% of the boys did so. For item 26, 82,4% of the females answered they often or always kept a safe distance, compared to 31,6% of the males.

In line with the correlation analysis, regarding age and violations a Fisher's exact test found significant differences for CBQ item 4, handling obstructive objects (p=0,002), and CBQ item 8, having a dispute or a race with another cyclist or driver (p=0,045). In both cases older cyclists indicated they performed these behaviours more frequently.

Table 4. CBQ Results of German Sample (Item content, dimension the item belongs to, mean (M), standard deviation (SD))

		Total German Sample		**Males German Sample**		**Females German Sample**	
Item	**Dimension**	M	SD	M	SD	M	SD
1. Cycling under the influence of alcohol and / or other drugs or hallucinogens.	Violations	0,34	0,81	0,53	1,07	0,18	0,39
2. Going against the direction of traffic (wrong way).		0,71	1,06	0,89	1,24	0,35	0,61
3. Zigzagging between vehicles when using a mixed lane.		0,45	0,83	0,58	0,84	0,18	0,53
4. Handle potentially obstructive objects while riding a bicycle (food, packs, cigarettes…).		1,00	0,90	1,00	0,88	0,76	0,66
5. Feeling that sometimes I'm going at a higher speed than I should be going at.		1,00	1,09	1,21	1,23	0,65	0,79
6. Crossing what appears to be a clear crossing, even if the traffic light is red.		1,08	1,22	1,26	1,33	0,71	0,99
7. Carry a passenger on your bicycle without it being adapted for such a purpose.		0,61	1,05	0,68	1,20	0,47	0,87
8. Have a dispute in speed or ''race" with another cyclist or driver.		0,61	0,89	0,89	0,99	0,24	0,56
9. Unintentionally, crossing the street without looking properly, making another vehicle brake to avoid a crash.	Errors	0,82	1,01	1,00	1,05	0,59	0,94
10. Colliding (or being close to it) with a pedestrian or another cyclist while cycling distractedly.		0,66	0,81	0,89	0,94	0,29	0,47
11. Brake suddenly and be close to causing an accident.		0,66	0,88	0,95	1,03	0,24	0,44
12. Fail to notice the presence of pedestrians crossing when turning.		0,68	0,99	0,95	1,18	0,35	0,61
13. Not braking on a ''Stop" or ''Yield" sign and being close to colliding with another vehicle or pedestrian.		0,87	1,14	1,05	1,08	0,71	1,26
14. Braking very abruptly on a slippery surface.		0,68	0,90	1,05	0,97	0,24	0,56
15. While you're distracted, you do not realize that a pedestrian intended to cross a crosswalk and so you do not stop to let him or her do so.		0,74	1,08	1,05	1,22	0,29	0,59
16. Not realizing that a vehicle that was parked intends to leave and having to brake abruptly to avoid colliding with it.		0,79	0,74	1,05	0,78	0,47	0,62
17. When you drive on the right, you do not realize that a passenger is getting out of a vehicle or bus and are close to hitting him or her.		0,55	0,76	0,74	0,87	0,35	0,61
18. Trying to overtake a vehicle that had previously used its indicators to signal that it was going to turn, having to brake.		0,68	1,09	0,89	1,24	0,41	0,87
19. Misjudging a turn and hitting something on the road or being close to losing balance (or falling).		0,39	0,75	0,53	0,90	0,29	0,59
20. Unintentionally, hitting a parked vehicle.		0,26	0,72	0,53	0,96	0,00	0,00
21. Failing to be aware of the road conditions and therefore falling over a bump or hole.		0,63	0,94	0,84	1,17	0,29	0,47
22. Mistaking one traffic signal for another and manoeuvring according to the latter.		0,45	0,80	0,68	1,00	0,18	0,39
23. Trying to brake but not being able to use the brakes properly due to poor hand positioning.		0,68	0,84	0,95	0,97	0,47	0,62
24. I stop and look both sides before crossing a corner or intersection.	Positive Behaviours	2,53	1,27	2,00	1,33	3,00	1,00
25. I try to move at a prudent speed to avoid sudden mishaps or braking.		2,71	1,21	2,21	1,32	3,24	0,83
26. I usually keep a safe distance from other cyclists or vehicles.		2,55	1,22	2,00	1,29	3,18	0,88
27. When I use the bike path (or bike-lane), I always use the indicated lane.		2,79	1,34	2,37	1,42	3,29	1,05
28. I avoid circulating under adverse weather conditions.		1,74	1,31	1,74	1,28	1,76	1,44
29. I avoid circulating if I feel very tired or sick.		2,11	1,43	1,68	1,29	2,53	1,55

4.1.5. Personality traits

The descriptive statistics for the Short Big Five Inventory (BSF-I) with respect to total and differentiated by gender are shown in Table A in the appendix. The mean values for the items are mostly very similar for both genders. A Fisher's exact test revealed significant differences only for item 11 (p=0,006) and item 12 (p=0,003), indicating that girls have higher values for agreeableness.

In a Fisher's exact test no significant differences were found for the frequency of traffic violations (question 10) and the BSF-I items. Regarding crashes in the last 3 years, only for BSF-I item 14 (I see myself as someone who tends to be lazy) a Fisher's exact test found a significant difference (p= 0,026). Participants who were involved in crashes indicated they were mostly neutral, or slightly agreed with this statement.

4.2. Belgium

4.2.1. Demographics and cycling habits

In total 55 participants filled out the questionnaire, 28 boys (50,9%) and 27 girls (49,1%) from 11 to 15 years with a mean age of 12,78 years (SD= 1,117). As primary school in Belgium covers 6 years and not 4 years as in Germany, 18,2% of the participants attended this type of school and 81,8% secondary school, most of them general secondary education (78,2%). Of the children 41,8% answered that they cycled daily and 38,2% weekly. A Fisher's exact test did not reveal any significant differences with respect to gender and cycling frequency. The majority indicated they cycled mostly with friends (45,5%), 32,7% alone, and 20% with their family. With respect to the reason for cycling multiple options were allowed, and 87,3% answered they used their bike to go to school 36,4% for leisure activities, 40% to go to friends and family, and 9% without a specific purpose, but because they liked cycling. Almost all participants responded that they used a standard bike (98,2%), and only 3,6% an e-bike.

4.2.2. Crashes and violations

Regarding compliance with traffic rules, 49,1% answered they regularly respected them when cycling, and 49,1% always, indicating a very law-abiding behaviour. Asked why they (sometimes) did not respect the traffic rules, 21,8% replied time constraints, 3,6% carelessness, 20% distraction and none to impress others.

Only very few of the children had been involved in a cycling crash in the last 3 years (10,9%), thereof 7,3% were involved once, 1,8% twice and 1,8% even 3 or more times. Of the participants who were involved in a cycling crash (n=6), one was a girl and 5 boys. A Fisher's exact test did not find any significant differences in crash frequency of boys and girls. The majority (66,7%) answered they had been the victim of the accident, 33,3% both victim and initiator, and no one only the initiator. Only one participant (16,7%) suffered no injuries, 83,3% slight injuries, and nobody severe injuries with stationary hospital treatment. A Fisher's exact test did not find any significant differences in injuries of boys and girls. The most common causes of the crash (all n=2; 33,3%) were poor cycling ability of others, incorrect road use of others, insufficient safety distance of others, not respecting the right of way of others, incorrect behaviour towards pedestrians of others, road conditions and obstacles. Other causes selected were incorrect road use of themselves, inappropriate speed of themselves or others, catch up errors of themselves or others, errors when driving side by side of others, errors when turning by themselves or others, non-compliance with lightning of themselves or others, drivers' errors of others, technical maintenance defects of themselves, and weather conditions.

4.2.3. Cycling skills and safety perception

Regarding cycling skills, 9,1% of the children answered that they estimated themselves to be a very good cyclist, 69,1% relatively good, 20% neutral and only 1,8% relatively bad. A Fisher's exact test did not reveal any significant differences with respect to cycling skills and gender. Most of the participants indicated they felt mostly safe (72,7%), 21,8% even very safe, and only 5,5% rather not. Those children who indicated they felt rather not safe were asked for the reasons allowing multiple choices. The most common replies were cars driving too fast (3; 100%), reckless car drivers (2; 66,7%), not enough separate cycle tracks (2; 66,7%), and passenger doors suddenly being opened (2; 66,7%).

4.2.4. Cycling Behaviour Questionnaire

In the case of the Belgian sample Cronbach's alpha revealed a poor reliability of the three CBQ dimensions (violations: $\alpha > 0{,}552$; errors: $\alpha > 0{,}693$; positive behaviours: $\alpha > 0{,}505$) and consequently the grouped dimensions were not considered further. The Spearman's bivariate correlation analysis found no significant correlations for age, gender, cycling frequency, respecting of traffic rules, crashes, and injuries. The results of the CBQ for the questionnaire in Belgium are shown in Table 5. The mean values for males and females do not show a differentiated picture for the dimensions of violations and errors, as sometimes males and sometimes females have a higher value. Also, for positive behaviours the mean values do not show gender specific differences and the mean values are mostly of similar size. A Fisher's exact test revealed significant differences for CBQ item 9 ($p=0{,}042$), but in this case 85,7% of the boys had answered that they never unintentionally crossed the street without looking properly, but only 59,3% of the girls. For CBQ item 17 a Fisher's exact test found significant differences ($p=0{,}035$), where 89,3% of the males had answered that the never were close to hitting passengers getting out of a vehicle, but only 63% of the girls.

Table 5. CBQ Results of Belgian Sample (Item content, dimension that the item belongs to, mean (M), standard deviation (SD))

		Total Belgian Sample		**Males Belgian Sample**		**Females Belgian Sample**	
Item	**Dimension**	M	SD	M	SD	M	SD
1. Cycling under the influence of alcohol and / or other drugs or hallucinogens.	Violations	0,00	0,00	0,00	0,00	0,00	0,00
2. Going against the direction of traffic (wrong way).		0,45	0,60	0,32	0,55	0,59	0,64
3. Zigzagging between vehicles when using a mixed lane.		0,27	0,49	0,29	0,46	0,26	0,53
4. Handle potentially obstructive objects while riding a bicycle (food, packs, cigarettes…).		0,56	0,81	0,57	0,84	0,56	0,80
5. Feeling that sometimes I'm going at a higher speed than I should be going at.		0,96	0,86	1,18	0,94	0,74	0,71
6. Crossing what appears to be a clear crossing, even if the traffic light is red.		0,40	0,83	0,57	1,03	0,22	0,51
7. Carry a passenger on your bicycle without it being adapted for such a purpose.		0,49	0,86	0,36	0,73	0,63	0,97
8. Have a dispute in speed or ''race" with another cyclist or driver.		0,29	0,66	0,43	0,84	0,15	0,36
9. Unintentionally, crossing the street without looking properly, making another vehicle brake to avoid a crash.	Errors	0,31	0,54	0,18	0,48	0,44	0,58
10. Colliding (or being close to it) with a pedestrian or another cyclist while cycling distractedly.		0,31	0,50	0,25	0,44	0,37	0,56
11. Brake suddenly and be close to causing an accident.		0,24	0,43	0,21	0,42	0,26	0,45
12. Fail to notice the presence of pedestrians crossing when turning.		0,36	0,49	0,29	0,46	0,44	0,51
13. Not braking on a ''Stop" or ''Yield" sign and being close to colliding with another vehicle or pedestrian.		0,27	0,45	0,32	0,48	0,22	0,42
14. Braking very abruptly on a slippery surface.		0,62	0,78	0,71	0,90	0,52	0,64
15. While you're distracted, you do not realize that a pedestrian intended to cross a crosswalk and so you do not stop to let him or her do so.		0,49	0,63	0,43	0,63	0,56	0,64
16. Not realizing that a vehicle that was parked intends to leave and having to brake abruptly to avoid colliding with it.		0,51	0,57	0,46	0,51	0,56	0,64
17. When you drive on the right, you do not realize that a passenger is getting out of a vehicle or bus and are close to hitting him or her.		0,25	0,48	0,11	0,31	0,41	0,57
18. Trying to overtake a vehicle that had previously used its indicators to signal that it was going to turn, having to brake.		0,07	0,26	0,07	0,26	0,07	0,27
19. Misjudging a turn and hitting something on the road or being close to losing balance (or falling).		0,51	0,57	0,50	0,64	0,52	0,51
20. Unintentionally, hitting a parked vehicle.		0,05	0,23	0,04	0,19	0,07	0,27
21. Failing to be aware of the road conditions and therefore falling over a bump or hole.		0,84	0,71	0,79	0,74	0,89	0,70
22. Mistaking one traffic signal for another and manoeuvring according to the latter.		0,60	0,66	0,50	0,58	0,70	0,72
23. Trying to brake but not being able to use the brakes properly due to poor hand positioning.		0,31	0,50	0,32	0,55	0,30	0,47
24. I stop and look both sides before crossing a corner or intersection.	Positive Behaviours	3,15	1,04	3,21	1,07	3,07	1,04
25. I try to move at a prudent speed to avoid sudden mishaps or braking.		2,40	1,10	2,18	1,16	2,63	1,01
26. I usually keep a safe distance from other cyclists or vehicles.		2,91	0,89	2,96	0,88	2,85	0,91
27. When I use the bike path (or bike-lane), I always use the indicated lane.		3,22	0,98	3,11	1,17	3,33	0,73
28. I avoid circulating under adverse weather conditions.		2,16	1,18	2,00	1,25	2,33	1,11
29. I avoid circulating if I feel very tired or sick.		2,56	1,13	2,50	1,23	2,63	1,04

4.3. Comparison of Germany and Belgium

The sample size (n=38 for Germany, n=55 for Belgium), and mean age of the participants was similar, with 12,87 years in Germany and 12,78 years in Belgium. Both samples showed an equilibrated participation of boys and girls, although in Germany the share of females was a bit lower than in Belgium, with 44,7% versus 49,1% in Belgium. On the other hand, 5,3% of the participants in Germany indicated they were diverse. Also, the cycling frequency of the participants was comparable, as in both cases around 80% answered they cycled daily or weekly. With respect to the violation of traffic norms, differences could be observed, as 21,1% of the German participants indicated they violated rules sometimes, and 13,2% even regularly, while only 1,8% of the Belgian participants regularly violated traffic rules

sometimes and no one sometimes. Likewise concerning the involvement in crashes in the last 3 years differences were reported, as 89,1% of the Belgian children answered they had not been involved in an accident, but only 68,9% of the German children. Consequently, more children from Germany reported they had been involved in one (23,7% vs. 7,3%) or two (5,3% vs. 1,8%) cycling crashes. However, the injury rate in Belgium was higher with 83,3% versus 41,7% in Germany.

A Mann-Whitney-U-Test was performed to verify if there were significant differences with respect to the items 1 to 29 of the CBQ between the German and the Belgian sample. The results are shown in Table B in the appendix. It was found that regarding violations significant differences at the 0,05-level existed for cycling under the influence of drugs or alcohol (item 1), handling potentially obstructive objects (items 4) and crossing red traffic lights (item 6). As can be seen in Table 4 and Table 5, the mean values are higher for German cyclists, both for males and females in all items, indicating German cyclists commit more violations than their Belgian peers. Interestingly, only for item 5, feeling to be going at a higher speed than on should, German and Belgian boys have similar mean values, higher than those of girls. Items 4, 5 and 6 were also the ones with the highest mean values of German children. For errors significant differences at the 0,05-level were found for making another vehicle brake to avoid a crash (item 9), colliding with other cyclists or pedestrians (item10), braking suddenly (item 11), not braking on a stop sign (item 13), trying to overtake a vehicle that has used its indicators (item 18) and not being able to break properly (item 23). For all items the means of the German cyclists were higher than those of the Belgian ones, and in all cases the means of the male cyclists were lower in Belgium compared to males in Germany. Interestingly, for items 9 and 10 the Belgian females reported higher means than their German peers. For positive behaviours only for item 24, stop and look before crossing, a significant difference was found. Consistently with the higher means for errors and violations by German children, in this case the Belgian children reported higher total mean values, indicating that they take more protective behaviour. Comparing gender, Belgian girls had a slightly higher mean than German girls for this item.

5. Discussion

5.1. Cycling behaviour of 10- to 15-year-old males and females

The objective of this study was to analyse the cycling behaviour (errors, violations, personality traits) of boys between 10 and 15 years compared to girls of the same age. The results show a mixed picture for Germany and Belgium.

For the German sample the results of the Cycling Behaviour Questionnaire indicate that boys show riskier behaviour than girls, as they have higher mean values for all items within the dimensions of errors and violations. For CBQ item 14 (belonging to errors), braking abruptly on slippery surface, the difference was found to be significant, and the results of Spearman's correlation analysis also indicate a significant positive association of gender and violations and gender and errors. When asked about the motives for not respecting traffic rules (question 11), girls and boys equally indicated time constraints, carelessness, and distractions, but only two males answered they did so to impress others. This may suggest that social desirability through spectacular actions is more relevant for boys, which might explain the higher mean values for violations. In their study on cyclists (mean age=32,82) in Latin America, Useche, Montoro, Tomas and Cendales (2018) also found that gender has an impact on the CBQ scores of traffic violations, where males reported higher values than women. However, Useche et al. (2018) did not find significant differences in errors with respect to gender. As no significant differences regarding skills were found in the survey, this does not seem to be an explanatory factor for errors by boys. A possible explanation for the higher error values of boys might be that they have a more inadequate risk perception than older cyclists and girls of the same age. The findings regarding errors and violations are also in line with the research by Stevens, Plumert, Cremer and Kearney (2012), who discovered that 10-year-old boys in the United States showed riskier cycling behaviour. Likewise, Feenstra, Ruiter, Schepers and Peters (2011) in a study on risky adolescent cycling behaviour observed that boys make more errors and violate traffic rules more frequently than girls. However, with respect to the frequency of infringements of traffic norms and crash frequency no significant differences were found among genders in the German sample. Since only 12 participants had been involved in an accident, thereof 58,33% males, the small sample

size can hardly be compared to official statistics, where 72% of the injured cyclists of the respective age group were males (Statistisches Bundesamt, 2021). Nevertheless, the significant difference in the severity of injuries and the higher means for errors and violations indicate that boys have a riskier cycling behaviour. Consistently, the results showed that gender and positive behaviours have a significant negative correlation, and females showed higher mean values for this dimension, with a significant difference for the safety distance kept (CBQ item 26). These results are in line with Useche et al. (2018) who also reported higher scores of females in positive cycling behaviours, suggesting that they employ more passive-safety elements and have a better risk perception.

Interestingly, for Belgian children the mean values of the CBQ did not show consistent differences with respect to gender and cycling behaviour, and only for two items related to errors significant differences were found, although in both cases girls showed higher values than boys. Furthermore, the correlation analysis did not reveal any significant associations concerning gender and crash frequency and severity of injuries respectively. Thus, regarding behaviour and crashes the findings are consistent within the survey. Five out of six (83,33%) of the participants involved in crashes were boys, however, due to the small sample size these numbers can hardly be compared to the official statistics in Belgium, stating that 64% of the injured cyclists between 0 to 17 years were males in 2021 (VIAS Institute, 2022). These results differ from the findings of Useche, Philippot, Ampe, Llamazares and Geus (2021), who in their study to validate the CBQ in Belgium (mean age of cyclists = 41,71) discovered males had higher rates of traffic violations, and females more positive behaviours. They also reported more risky behaviours of cyclists under 30. The discrepancy of the results of the Belgian sample with the official statistics on cycling crashes, indicating that gender differences exist for younger cyclists, and Useche et. al (2021) who found adult male cyclists committed more violations, could be due to the laboratory setting of the study, which might have biased the answers as participants felt more observed than in an online survey. Another explanation might be that the participants have a good risk perception and awareness of traffic norms, for example through training. As this was not assessed in the study, the hypothesis cannot be ultimately confirmed.

5.2. Common causes of crashes of 10- to 15-year-old cyclists

One sub research question of the study was to analyse the reported causes of crashes. Regarding the German sample, where 12 participants had been involved in crashes in the last 3 years, thereof 33,3% as a victim, the causes of crashes coincide with the German Federal Statistical Office concerning the most common misbehaviour being incorrect road use (18%) for the age group of under 15 (Statistisches Bundesamt, 2021).Thus, the findings indicate that independent of gender the correct road use should be trained and supported through adequate infrastructure. However, none of the respondents indicated misbehaviour when turning, reversing, driving in and starting up as a cause of crash, which is ranked second with 17% in the official statistics for the respective age group (Statistisches Bundesamt, 2021). Other common causes such as not respecting the right of way (10%), or inappropriate speed (8%) had also been indicated by the participants of the survey. Poor driving ability of the cyclists was indicated by two males (16%), although this played only a minor role in the official statistics with 0,5%.

From the Belgian sample 6 participants had been involved in crashes and the most common causes of crashes were related to incorrect behaviour of others, such as poor cycling ability, incorrect road use, insufficient safety distance, not respecting the right of way and behaviour towards pedestrians. These results are in line with the statement that the children had mostly been the victim of the crash (66,7%), suggesting that the behaviour of other road users should be improved and cycling infrastructure made safer.

5.3. Cycling behaviour of 10-to-15-year-olds and relation to personality traits in Germany

In the German version of the questionnaire personality traits were included to analyse if they influence cycling behaviour. The mean values of boys and girls were similar, and only for items related to agreeableness significant differences were found. However, no significant differences for infringements of traffic rules were observed, therefore the study does not provide evidence for the relation of personality traits and cycling behaviour of children. In contrast, Useche et al. (2022) found that personality traits were related to risky cycling behaviour, specifically

conscientiousness and agreeableness had a negative correlation to errors and violations, and extraversion and neuroticism a positive correlation to risky behaviours. A possible explanation for this discrepancy is that personality traits do not directly influence the cycling behaviour and crashes in children, as some do in adults. However, the sample may also have been too small to prove such correlations.

5.4. Comparison of cycling behaviours of 10- to 15-year-old cyclists in Germany and Belgium

Although the number and the mean age of the participants from Germany and Belgium was similar, important differences in the cycling behaviour were observed. In general, German children violated traffic norms more frequently (13,2%), while only very few Belgian children indicated to do so regularly (1,8%). The higher share of German children (31,1% vs. 10,9%) involved in crashes in the last 3 years is therefore consistent.

The results of the Mann-Whitney-U Test likewise showed significant differences with respect to 3 items related to violations, revealing that German cyclists committed more violations. Since violations are voluntary behaviours, these findings imply that German cyclists from 10 to 15 years are more reckless, which may be due to an insufficient promotion of safe cycling practices, traffic education and regulation (Useche, Montoro, Tomas, & Cendales, 2018). Only speeding seems to be an issue both for boys in Germany and Belgium. Similarly for errors, in six CBQ items significant differences were found, again exposing German children made more errors. Since errors are not intentional, they may be due to insufficient skills or lacking risk perception. The self-assessment of skills for both countries was similar, with 78,2% of Belgian children evaluating themselves as good or very good cyclist and 76,3% of the German children, therefore the higher number of errors may rather be explained from an inadequate risk perception of German cyclists. For positive behaviours only for one item a significant difference was found. In line with the previous findings Belgian cyclists showed higher mean values, which further supports the hypothesis that they have a better risk perception than their German peers.

6. Limitations and future research

6.1. Germany

The most important limitation of the online survey is the limited size of the study sample, with 38 participants. The results are therefore not representative and furthermore subject to geographical concentration in some regions, such as Hürth (29%) and Darmstadt (16%).

It should be considered that the online tool used for the survey may have restricted the participation, as some children may have only constrained access to mobile phones or computers, or not commonly use these devices.

Since the study was held online, without a direct interaction with participants, they were not able to verify possible doubts regarding the understanding of questions. However, this limitation is expected to be minimal, as several elements of the survey were already validated in other studies and the questionnaire was thoroughly checked in an interactive process with the thesis supervisor.

Moreover, the results are based on self-reported information regarding behaviour and personality, which may be biased by the own perception and considered sensitive. To account for this, participants were informed that the survey was anonymous, and the data only used for a Master's Thesis, and not for commercial purposes.

The study also used cross-sectional data, measuring current behaviour and past crash experiences. The crash experience is therefore more likely to impact the current behaviour, while the past behaviour leading to the accident is more difficult to measure.

The participants may furthermore already have forgotten about the near accidents or accidents without severe damage, therefore underrepresenting the past incidents. Evidence for this phenomenon was presented in a study showing that 80% of the incidents were not recalled anymore after only two weeks (Chapman & Underwood, 2000).

6.2. Survey in Belgium

Likewise to the online survey in Germany, the survey conducted in Belgium with 55 participants is not representative for the analysed population group either. In this case too, the results are subject to a geographical concentration, which is even stronger, as all participants are from the city of Hasselt and surroundings.

As for the case of the online survey in Germany, the information is self-reported and may therefore be biased. Furthermore, the mentioned limitations of cross-sectional data and the possibility that participants have already forgotten past accidents, apply to the survey conducted in Belgium too.

However, participants filled out the survey at a lab at Hasselt University and were therefore able to ask directly for help with technical devices or if they did not understand questions, which was not the case with the online survey in Germany. On the other hand, being in a laboratory, Belgian children may have felt more observed, which may have influenced their answers. The fact that in the first question of the CBQ none of them indicated having used drugs, whereas German children did, supports this possible limitation.

7. Practical implications

This study aimed to assess the cycling behaviour of boys and girls in Germany and Belgium, and how this relates to cycling crashes. For German cyclists from 10 to 15 years, boys were found to show riskier cycling behaviour and suffer more severe injuries. A crucial aspect of formulating intervention strategies is identifying the specific individuals and factors that should be targeted for intervention. Therefore, differences in risk perception, motives for traffic violations and crash scenarios should be further investigated with a larger sample, to consider gender specific elements in traffic education, policymaking and cycling infrastructure. In general, the higher values of German cyclists regarding errors and violations indicate that they are more reckless and have a lower risk perception, which should be addressed in long trainings and educational programmes. The Belgian cycling education might serve as a reference for the design of these programmes and should be compared to German cycling education.

Furthermore, the findings in Belgium, indicating no gender specific differences in cycling behaviour, should be validated in another study with a bigger sample and a more equilibrated geographical distribution, as the official statistics indicate that boys are more often injured and killed in cycling crashes. It should also be critically reflected if the setting of the study in a laboratory influenced the answers.

8. Conclusions

Regarding the goal of the study, the results suggest that gender plays a significant role in cycling behaviour of children in Germany. The findings emphasise the need for targeted intervention strategies to address the riskier cycling behaviour observed among German boys, who are more prone to errors, violations, and severe injuries. Examples of intervention strategies are outlined in Appendix D. Factors such as risk perception, motives for traffic violations, and crash scenarios should be further explored to consider gender-specific elements in traffic education, policymaking, and cycling infrastructure.

However, for Belgium no significant gender specific differences could be observed, although the official statistics indicate boys are more often injured and killed in cycling crashes. Hence, further research with larger and more representative samples is recommended to validate the results.

Finally, the findings indicate that German children from 10 to 15 years have a riskier cycling behaviour than their Belgian peers, which may be due to more carelessness and poorer risk perception. Therefore, educational cycling programmes in Germany should be analysed and compared to the Belgian cycling education model, to identify possibilities for improvement to enhance the safety of children when cycling.

Appendix A. Online Survey for Germany – English Version

Welcome to this survey on cycling behaviour! This study is not commercial and is being conducted as part of a master's thesis at Hasselt University.

Please give your honest opinion. The survey is anonymous, and responses will be analysed confidentially. There are no right or wrong answers.

You have the possibility to stop whenever you want. The survey takes approximately 10 minutes to fill in.

To start the survey, please agree to participate: *(If participants do not agree, they are directed to the end of the survey)*

☐ I agree to participate.

☐ I disagree to participate.

Entry questions

1. How old are you?
   ☐ 9 years or younger
   ☐ 10 years
   ☐ 11 years
   ☐ 12 years
   ☐ 13 years
   ☐ 14 years
   ☐ 15 years
   ☐ 16 years or older

2. What is your gender?
   ☐ Female
   ☐ Male
   ☐ Diverse

3. What type of school do you go to?
   ☐ Primary school
   ☐ Secondary school

4. What is your postal code?

   Click or tap here to enter text.

5. How often do you cycle?
   ☐ Daily
   ☐ Weekly
   ☐ Monthly
   ☐ Yearly

6. In whose company do you mostly cycle?
   ☐ I mostly cycle alone
   ☐ I mostly with friends
   ☐ I mostly cycle with my family

☐ Other Click or tap here to enter text.

7. For which reason do you use your cycle? *(Multiple answers possible)*
   ☐ To go to school
   ☐ To go to leisure activities
   ☐ To go to friends and family
   ☐ Nowhere specific, I just cycle because I like cycling.
   ☐ Other Click or tap here to enter text.

8. Which kind of cycle do you use? *(Multiple answers possible)*
   ☐ Standard bicycle
   ☐ Electric bicycle

9. Do you use protective equipment when cycling?
   ☐ No
   ☐ Helmet
   ☐ Florescent jackets, wests, or other florescent elements
   ☐ Protectors
   ☐ Other Click or tap here to enter text.

Self-reported crashes and infringements

10. How often do you violate the traffic rules when cycling?
    ☐ never
    ☐ seldom
    ☐ sometimes
    ☐ regularly
    ☐ always

11. Why did you violate traffic rules? *(Multiple answers possible. Only shown if Q10 is answered with "seldom", "sometimes", "regularly" or "always", otherwise the participant is directed to the next section.)*
    ☐ Time constraints
    ☐ Carelessness
    ☐ Distraction
    ☐ To impress others
    ☐ Other Click or tap here to enter text.

12. How many times were you involved in a crash while cycling in the last 3 years?
    ☐ 0
    ☐ 1
    ☐ 2
    ☐ 3
    ☐ 4
    ☐ 5
    ☐ 6 or more

13. Were you the victim or the initiator of the accident(s)? *(Only shown if Q12 is answered with more than 0, otherwise the participant is directed to the next section.)*
    ☐ Initiator
    ☐ Victim
    ☐ Both

14. Were you injured as a consequence of a cycling crash in the last 3 years? *(Only shown if Q12 is answered with more than 0, otherwise the participant is directed to the next section.)*
    ☐ No.
    ☐ Yes, severely injured. (i.e., immediate stationary treatment of at least 24 hours in a hospital)
    ☐ Yes, slightly injured. (i.e., all other injuries)

15. What was the cause of the crash? *(Multiple answers possible. Only shown if Q12 is answered with more than 0, otherwise the participant is directed to the next section.)*
    ☐ Poor driving ability (e.g., under the influence of alcohol, overtiredness, physical deficiencies) of myself
    ☐ Poor driving ability (e.g., under the influence of alcohol, overtiredness, physical deficiencies) of others
    ☐ Incorrect road use (i.e., contrary to the prescribed direction of travel) of myself
    ☐ Incorrect road use (i.e., contrary to the prescribed direction of travel) of others
    ☐ Inappropriate speed of myself
    ☐ Inappropriate speed of others
    ☐ Insufficient safety distance of myself
    ☐ Insufficient safety distance of others
    ☐ Overtaking error of myself
    ☐ Overtaking error of others
    ☐ Passing error of myself
    ☐ Passing error of others
    ☐ Error when driving side by side of myself
    ☐ Error when driving side by side of others
    ☐ Not respecting the right of way or priority of myself
    ☐ Not respecting the right of way or priority of others
    ☐ Errors when turning, reversing, driving in and starting up of myself
    ☐ Errors when turning, reversing, driving in and starting up of others
    ☐ Incorrect behaviour towards pedestrians of myself
    ☐ Incorrect behaviour towards pedestrians of others
    ☐ Stationary traffic or traffic safety (i.e., Unauthorized stopping or parking, entering or exiting, loading or unloading)
    ☐ Non-compliance with the lighting regulations of myself
    ☐ Non-compliance with the lighting regulations of others
    ☐ Error in loading or occupation of myself
    ☐ Error in loading or occupation of others
    ☐ Other driver errors of myself
    ☐ Other driver errors of others
    ☐ Technical or maintenance defects of myself
    ☐ Wrong behaviour of pedestrians
    ☐ Road conditions
    ☐ Weather conditions

☐ Obstacles
☐ Other Click or tap here to enter text.

Cycling Behaviour Questionnaire

16. Estimate how often you do the following when cycling:

Item	**Frequency**				
	Never	Rarely	Sometimes	Often	Always
1. Cycling under the influence of alcohol and / or other drugs or hallucinogens.					
2. Going against the direction of traffic (wrong way).					
3. Zigzagging between vehicles when using a mixed lane.					
4. Handle potentially obstructive objects while riding a bicycle (food, packs, cigarettes…).					
5. Feeling that sometimes I'm going at a higher speed than I should be going at.					
6. Crossing what appears to be a clear crossing, even if the traffic light is red.					
7. Carry a passenger on your bicycle without it being adapted for such a purpose.					
8. Have a dispute in speed or ''race" with another cyclist or driver.					
9. Unintentionally, crossing the street without looking properly, making another vehicle brake to avoid a crash.					
10. Colliding (or being close to it) with a pedestrian or another cyclist while cycling distractedly.					
11. Brake suddenly and be close to causing an accident.					
12. Fail to notice the presence of pedestrians crossing when turning.					
13. Not braking on a ''Stop" or ''Yield" sign and being close to colliding with another vehicle or pedestrian.					
14. Braking very abruptly on a slippery surface.					
15. While you're distracted, you do not realize that a pedestrian intended to cross a crosswalk and so you do not stop to let him or her do so.					
16. Not realizing that a vehicle that was parked intends to leave and having to brake abruptly to avoid colliding with it.					
17. When you drive on the right, you do not realize that a passenger is getting out of a vehicle or bus and are close to hitting him or her.					
18. Trying to overtake a vehicle that had previously used its indicators to signal that it was going to turn, having to brake.					
19. Misjudging a turn and hitting something on the road or being close to losing balance (or falling).					
20. Unintentionally, hitting a parked vehicle.					

Item	**Frequency**				
	Never	Rarely	Sometimes	Often	Always
21. Mistaking one traffic signal for another and manoeuvring according to the latter.					
22. Trying to brake but not being able to use the brakes properly due to poor hand positioning.					
23. I stop and look both sides before crossing a corner or intersection.					
24. I try to move at a prudent speed to avoid sudden mishaps or braking.					
25. I usually keep a safe distance from other cyclists or vehicles.					
26. When I use the bike path (or bike-lane), I always use the indicated lane.					
27. I avoid circulating under adverse weather conditions.					
28. I avoid circulating if I feel very tired or sick.					

17. How do you estimate yourself as a cyclist?
    - ☐ Very good
    - ☐ Good
    - ☐ Neutral
    - ☐ Bad
    - ☐ Very bad

18. Do you feel safe when cycling in road traffic?
    - ☐ Yes, very safe
    - ☐ Yes, mostly
    - ☐ No, rather not
    - ☐ No, not at all

19. Why do you not feel safe when cycling in road traffic? *(Multiple answers possible. Only shown if Q19 is answered with "No, rather not" or "No, not at all", otherwise the participant is directed to the next section.)*
    - ☐ Too much traffic
    - ☐ Reckless car drivers
    - ☐ Not enough separate cycle tracks
    - ☐ Cars driving too fast
    - ☐ Too much heavy goods vehicle traffic
    - ☐ Passenger car doors suddenly being opened
    - ☐ Reckless cyclists
    - ☐ Cars stopping on cycle tracks
    - ☐ Cycle tracks in poor condition
    - ☐ Different speeds of other cyclists
    - ☐ Lack of experience
    - ☐ Because of my physical condition
    - ☐ Other Click or tap here to enter text.

Personality

20. Please answer how you see yourself according to the following scale:

I see myself as someone who …							
	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
1. Worries a lot							
2. Gets nervous easily							
3. Remains calm in tense situations.							
4. Is talkative							
5. Is outgoing, sociable							
6. Is reserved							
7. Is original, comes up with new ideas							
8. Values artistic, aesthetic experiences							
9. Has an active imagination							
10. Is sometimes rude to others							
11. Has a forgiving nature							
12. Is considerate and kind to almost everyone							
13. Does a thorough job							
14. Tends to be lazy							
15. Does things efficiently							

End

Thank you for the time and effort to fill in this survey!

A total of 5 Amazon vouchers worth 20 euros each will be raffled to the participants. The winners will be contacted at the beginning of April 2023.

If you wish to participate in the raffle of Amazon vouchers, please click on the following link https://uhasselt.qualtrics.com/jfe/form/SV_bmvku24Kxe7UYNU and enter your e-mail address.

Appendix B. Questionnaire for Belgium – English Version

1. How old are you?
   ☐ 10 years
   ☐ 11 years
   ☐ 12 years
   ☐ 13 years
   ☐ 14 years
   ☐ 15 years
   ☐ 16 years or older

2. What is your gender?
   ☐ Female
   ☐ Male

3. What type of school do you go to?
   ☐ Primary school
   ☐ Secondary school
   ☐ Other:

4. What field of study are you following?
   ☐ General secondary education
   ☐ Technical secondary education
   ☐ Vocational secondary education
   ☐ Art secondary education
   ☐ Other Click or tap here to enter text.
   ☐ Not applicable, e.g. primary education

5. How often do you cycle?
   ☐ Daily
   ☐ Weekly
   ☐ Monthly
   ☐ Yearly

6. In whose company do you mostly cycle?
   ☐ I mostly cycle alone
   ☐ I mostly with friends
   ☐ I mostly cycle with my family
   ☐ Other Click or tap here to enter text.

7. For which reason do you use your cycle? *(Multiple answers possible)*
   ☐ To go to school
   ☐ To go to leisure activities
   ☐ To go to friends and family
   ☐ Nowhere specific, I just cycle because I like cycling.
   ☐ Other Click or tap here to enter text.

8. Which kind of cycle do you use? *(Multiple answers possible)*
   ☐ Standard bicycle
   ☐ Electric bicycle
   ☐ Other Click or tap here to enter text.

9. Do you use protective equipment when cycling? *(Multiple answers possible)*
   ☐ No
   ☐ Helmet
   ☐ Florescent jackets, wests, or other florescent elements
   ☐ Protectors
   ☐ Other Click or tap here to enter text.

10. Do you respect traffic rules while cycling?
    ☐ never
    ☐ seldom
    ☐ sometimes
    ☐ regularly
    ☐ always

11. Why don't you respect traffic rules (sometimes)? *(Multiple answers possible)*
    ☐ Time constraints
    ☐ Carelessness
    ☐ Distraction
    ☐ To impress others
    ☐ Other Click or tap here to enter text.

12. How many times were you involved in a crash while cycling in the last 3 years?
    ☐ 0
    ☐ 1
    ☐ 2
    ☐ 3
    ☐ 4
    ☐ 5
    ☐ 6 or more

13. Were you injured as a consequence of a cycling crash in the last 3 years?
    ☐ No.
    ☐ Yes, serious injuries (e.g. immediate hospital treatment)
    ☐ Yes, slightly injured. (e.g. scrapes, bruises...)

14. What was the cause of the crash? *(Multiple answers possible. Only shown if Q12 is answered with more than 0, otherwise the participant is directed to the next section.)*
    ☐ Poor cycling ability (e.g. fatigue...) of myself
    ☐ Poor cycling ability (e.g. fatigue...) of others
    ☐ Incorrect road use (i.e., contrary to the prescribed direction of travel) of myself
    ☐ Incorrect road use (i.e., contrary to the prescribed direction of travel) of others
    ☐ Inappropriate speed of myself

☐ Inappropriate speed of others
☐ Insufficient safety distance of myself
☐ Insufficient safety distance of others
☐ Catch-up error of myself
☐ Catch-up error of others
☐ Error when driving side by side of myself
☐ Error when driving side by side of others
☐ Not respecting the right of way or priority of myself
☐ Not respecting the right of way or priority of others
☐ Errors when turning, reversing, … of myself
☐ Errors when turning, reversing, … of myself
☐ Incorrect behaviour towards pedestrians of myself
☐ Incorrect behaviour towards pedestrians of others
☐ Stationary traffic or traffic safety (i.e., Unauthorized stopping or parking, entering or exiting, loading or unloading)
☐ Non-compliance with the lighting regulations of myself
☐ Non-compliance with the lighting regulations of others
☐ Other driver errors of myself
☐ Other driver errors of others
☐ Technical or maintenance defects of myself
☐ Technical or maintenance defects of others
☐ Wrong behaviour of pedestrians
☐ Road conditions
☐ Weather conditions
☐ Obstacles
☐ Other Click or tap here to enter text.

Cycling Behaviour Questionnaire

15. Estimate how often you do the following when cycling:

Item	**Frequency**				
	Never	Rarely	Sometimes	Often	Always
1. Cycling under the influence of alcohol and / or other drugs or hallucinogens.					
2. Going against the direction of traffic (wrong way).					
3. Zigzagging between vehicles when using a mixed lane.					
4. Handle potentially obstructive objects while riding a bicycle (food, packs, cigarettes…).					
5. Feeling that sometimes I'm going at a higher speed than I should be going at.					
6. Crossing what appears to be a clear crossing, even if the traffic light is red.					
7. Carry a passenger on your bicycle without it being adapted for such a purpose.					
8. Have a dispute in speed or ''race" with another cyclist or driver.					

Item	**Frequency**				
	Never	Rarely	Sometimes	Often	Always
9. Colliding (or being close to it) with a pedestrian or another cyclist while cycling distractedly.					
10. Brake suddenly and be close to causing an accident.					
11. Fail to notice the presence of pedestrians crossing when turning.					
12. Not braking on a ''Stop" or ''Yield" sign and being close to colliding with another vehicle or pedestrian.					
13. Braking very abruptly on a slippery surface.					
14. While you're distracted, you do not realize that a pedestrian intended to cross a crosswalk and so you do not stop to let him or her do so.					
15. Not realizing that a vehicle that was parked intends to leave and having to brake abruptly to avoid colliding with it.					
16. When you drive on the right, you do not realize that a passenger is getting out of a vehicle or bus and are close to hitting him or her.					
17. Trying to overtake a vehicle that had previously used its indicators to signal that it was going to turn, having to brake.					
18. Misjudging a turn and hitting something on the road or being close to losing balance (or falling).					
19. Unintentionally, hitting a parked vehicle.					
20. Failing to be aware of the road conditions and therefore falling over a bump or hole.					
21. Mistaking one traffic signal for another and manoeuvring according to the latter.					
22. Trying to brake but not being able to use the brakes properly due to poor hand positioning.					
23. I stop and look both sides before crossing a corner or intersection.					
24. I try to move at a prudent speed to avoid sudden mishaps or braking.					
25. I usually keep a safe distance from other cyclists or vehicles.					
26. When I use the bike path (or bike-lane), I always use the indicated lane.					
27. I avoid circulating under adverse weather conditions.					
28. I avoid circulating if I feel very tired or sick.					

16. How do you estimate yourself as a cyclist?

☐ Very bad
☐ Relatively good
☐ Neutral
☐ Relatively bad

☐ Very good

17. Do you feel safe when cycling in road traffic?
☐ No, not at all
☐ No, rather not
☐ Yes, mostly
☐ Yes, very safe

18. Why do you not feel safe when cycling in road traffic? *(Multiple answers possible.)*
☐ Too much traffic
☐ Reckless car drivers
☐ Reckless cyclists
☐ Not enough separate cycle tracks
☐ Cycle tracks in poor condition
☐ Cars driving too fast
☐ Too much heavy goods vehicle traffic
☐ Passenger car doors suddenly being opened
☐ Cars stopping on cycle tracks
☐ Different speeds of other cyclists
☐ Lack of experience
☐ Because of my physical condition
☐ Other Click or tap here to enter text.

Appendix C. Supplementary material

Table A. Descriptive statistics for Short Big Five Inventory (BSF-I) of German Sample

I see myself as someone who…	Total German Sample		Female		Male	
	M	SD	M	SD	M	SD
1. worries a lot (N)	3,39	1,82	4,24	1,71	2,63	1,64
2. gets nervous easily (N)	3,29	1,72	4,18	1,55	2,42	1,39
3. remains calm in tense situations (N, recoded)	4,18	1,61	4,29	1,61	4,05	1,65
4. is talkative (E)	4,61	1,82	5,24	1,86	4,00	1,73
5. is outgoing, sociable (E)	4,58	1,94	4,76	2,08	4,47	1,93
6. is reserved (E, recoded)	4,18	1,94	4,47	1,97	4,00	1,86
7. is original, comes up with new ideas (O)	4,61	1,69	4,88	1,90	4,37	1,50
8. values artistic, aesthetic experiences (O)	4,74	1,61	4,71	1,99	4,63	1,26
9. has an active imagination (O)	4,97	1,75	5,18	1,78	4,68	1,80
10. is sometimes rude to others (A, recoded)	4,74	1,69	4,88	1,90	4,68	1,45
11. has a forgiving nature (A)	5,16	1,44	5,76	1,52	4,63	1,26
12. is considerate and kind to almost everyone (A)	5,18	1,71	5,94	1,68	4,47	1,47
13. does a thorough job (C)	4,26	1,84	5,18	1,51	3,26	1,63
14. tends to be lazy (C, recoded)	4,39	1,69	4,65	1,73	4,32	1,57
15. does things efficiently (C)	4,42	1,72	5,06	1,48	3,68	1,67

Total= 38, Female= 17, Male= 19, Diverse=2.

N Neuroticism, E Extraversion, O Openness to experience, A Agreeableness, C Conscientiousness

Table B. Mann-Whitney U Test on CBQ items for German and Belgian sample

Item	Dimension	Mann-Whitney U	Z-score	Significance at 0.05 level	Decision
1. Cycling under the influence of alcohol and / or other drugs or hallucinogens.	Violations	825,00	-3,537	0,00	Reject the null hypothesis.
2. Going against the direction of traffic (wrong way).		975,00	-0,626	0,53	Retain the null hypothesis.
3. Zigzagging between vehicles when using a mixed lane.		998,50	-0,475	0,63	Retain the null hypothesis.
4. Handle potentially obstructive objects while riding a bicycle (food, packs, cigarettes…).		738,00	-0,261	0,01	Reject the null hypothesis.
5. Feeling that sometimes I'm going at a higher speed than I should be going at.		1077,00	0,269	0,79	Retain the null hypothesis.
6. Crossing what appears to be a clear crossing, even if the traffic light is red.		696,00	-3,150	0,00	Reject the null hypothesis.
7. Carry a passenger on your bicycle without it being adapted for such a purpose.		1009,50	-0,034	0,73	Retain the null hypothesis.
8. Have a dispute in speed or ''race" with another cyclist or driver.		855,00	-1,909	0,06	Retain the null hypothesis.
9. Unintentionally, crossing the street without looking properly, making another vehicle brake to avoid a crash.	Errors	757,00	-2,637	0,01	Reject the null hypothesis.
10. Colliding (or being close to it) with a pedestrian or another cyclist while cycling distractedly.		814,50	-2,123	0,03	Reject the null hypothesis.
11. Brake suddenly and be close to causing an accident.		785,50	-2,474	0,01	Reject the null hypothesis.
12. Fail to notice the presence of pedestrians crossing when turning.		932,50	-1,027	0,30	Retain the null hypothesis.
13. Not braking on a ''Stop" or ''Yield" sign and being close to colliding with another vehicle or pedestrian.		780,00	-2,465	0,01	Reject the null hypothesis.
14. Braking very abruptly on a slippery surface.		1032,00	-0,113	0,91	Retain the null hypothesis.
15. While you're distracted, you do not realize that a pedestrian intended to cross a crosswalk and so you do not stop to let him or her do so.		990,00	-0,049	0,62	Retain the null hypothesis.
16. Not realizing that a vehicle that was parked intends to leave and having to brake abruptly to avoid colliding with it.		837,00	-1,815	0,07	Retain the null hypothesis.
17. When you drive on the right, you do not realize that a passenger is getting out of a vehicle or bus and are close to hitting him or her.		848,00	-1,915	0,06	Retain the null hypothesis.
18. Trying to overtake a vehicle that had previously used its indicators to signal that it was going to turn, having to brake.		722,00	-3,667	0,00	Reject the null hypothesis.
19. Misjudging a turn and hitting something on the road or being close to losing balance (or falling).		1221,00	1,603	0,11	Retain the null hypothesis.
20. Unintentionally, hitting a parked vehicle.		958,50	-1,390	0,16	Retain the null hypothesis.
21. Failing to be aware of the road conditions and therefore falling over a bump or hole.		1269,00	1,900	0,06	Retain the null hypothesis.
22. Mistaking one traffic signal for another and manoeuvring according to the latter.		1229,50	1,640	0,10	Retain the null hypothesis.
23. Trying to brake but not being able to use the brakes properly due to poor hand positioning.		806,50	-2,193	0,03	Reject the null hypothesis.
24. I stop and look both sides before crossing a corner or intersection.	Positive Behaviours	1362,50	2,623	0,01	Reject the null hypothesis.
25. I try to move at a prudent speed to avoid sudden mishaps or braking.		854,50	-1,549	0,12	Retain the null hypothesis.
26. I usually keep a safe distance from other cyclists or vehicles.		1213,00	1,408	0,16	Retain the null hypothesis.
27. When I use the bike path (or bike-lane), I always use the indicated lane.		1208,50	1,369	0,17	Retain the null hypothesis.
28. I avoid circulating under adverse weather conditions.		1251,00	1,653	0,10	Retain the null hypothesis.
29. I avoid circulating if I feel very tired or sick.		1235,00	1,525	0,13	Retain the null hypothesis.

Appendix D. Possible intervention strategies

The study found that boys in Germany showed a riskier cycling behaviour than girls, as they had higher mean values in all items of the CBQ regarding errors and violations. Errors are usually not intentional and stem from insufficient skills or inadequate risk perception (Useche, Montoro, Tomas, & Cendales, 2018). As no significant differences in skills were observed, boys might have a poorer risk perception. CBQ item 14, braking very abruptly on a slippery surface, belonging to errors, was found be significant regarding gender differences. This behaviour which was more frequent in boys also indicates an inadequate risk perception. The awareness of road traffic and decision-making can be improved trough cycling trainings; however, it is important to consider that these trainings are often too short with less than 10 hours (Lenton & Finlay, 2018). Consistently, the impact of such trainings on injury reduction is not significant (Richmond, Zhang, Stover, Howard, & Macarthur, 2014). The authors state that there is a lack of high-quality research on cycling training programmes. Lenton and Finlay (2018) recommend trainings should last around 100 hours to achieve a better cycling expertise and be more focused on decision making instead of physical competency. These comprehensive trainings should be school-based and could include virtual reality programmes to better assess the cycling competence (Lenton & Finlay, 2018).

Also for violations higher mean values were observed among German boys. Since violations are intentional, road safety attitudes should likewise be addressed in cycling trainings, taking into account that males might be seeking more attention, which is supported by the result that only boys responded they violated traffic norms to impress others. As for positive behaviours higher mean values were reported by German girls, protective behaviours such as keeping a safe distance from other vehicles should be underlined in trainings, as they are effective to strengthen cyclists' safety (Useche, Montoro, Tomas, & Cendales, 2018).

Another aspect to be targeted by intervention strategies is the significant gender difference found in the severity of crashes of German children. Injuries might be prevented from helmet use, which should be encouraged, considering correct fitting and standards (Lenton & Finlay, 2018). However, injuries should also be mitigated by lower speed limits and supportive physical structures, as well as high-quality connected cycling paths which are separate from motorised traffic (Lenton & Finlay, 2018).

With respect to Belgian children no consistent differences regarding gender and cycling behaviour were observed and in general the mean values were lower than in the German sample for the CBQ items. Nevertheless, for CBQ item 9 (unintentionally crossing the street without looking properly, making another vehicle brake to avoid a crash), and for item 17, (when you drive on the right, you do not realize that a passenger is getting out of a vehicle or bus and are close to hitting him or her) significant gender differences were found. Both items are errors which are related to an insufficient perception of other road users. To train this interaction with real road traffic, virtual reality programmes might be useful. The relatively high mean value of Belgian boys on CBQ item 5 concerning speeding, which is similar to the level on German boys, should be addressed in training programmes, where adequate speed is trained and the consequences of higher speed in crashes are explained.

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