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# IDENTIFYING CYCLING PATTERNS, RELATED PSYCHOSOCIAL CHARACTERISTICS AND PREDICTORS OF BICYCLE CRASHES

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# Abstract

Cycling is a cheap and flexible mean of transportation which holds many benefits in terms of personal and public health. It contributes to reducing pollution and increasing the levels of physical activity of users. However, it still holds risks in term of safety, and the number of casualties due to cycling crashes in recent years are not decreasing considerably. Furthermore, to achieve the highest results in terms of benefits for the population, it is still necessary to find ways to make cycling largely widespread. Several studies have explored factors related to cycling use and cycling safety, but many authors argued that psychosocial factors are still fairly neglected in cycling studies. The present thesis attempts to address these issues with the intent of yielding to useful insights which can be used by policymakers and professionals to design intervention for increasing cycling use and safety. Our work comprises four studies and is divided into two main sections: the first part focusses on cycling use patterns and attitudes towards cycling while the second focuses on cycling safety. Both sections include a particular focus on gender differences in cycling use and safety. In Study 1, we attempted to identify clusters of cyclists based on cycling motivation and patterns at a European level and profiled the membership to each cluster according to socio-demographics and attitudes. Following a cross-sectional design, we collected data from 2417 participants from Hungary, Italy, Spain, Sweden, Netherlands, and United Kingdom. The main contribution of this study is to highlight commonalities in patterns, characteristics and attitudes of cyclists in six different European countries. We showed that cycling patterns and habits are linked to culture as well as attitudes and evaluation of the cycling environment, explicitly highlighting the importance of the feeling of discomfort in mixed traffic and the evaluation of cycling infrastructures. In Study 2 we focused on inequalities of the population in bicycle use, particularly investigating gender differences. Previous research has, in fact, suggested that the benefits of cycling are not evenly distributed among women and men. Studies have shown that men cycle more than women and women tend to report less favourable perceptions and attitudes towards cycling than men. Gender differences in perceptions and attitudes towards cycling may be influenced by such difference in bicycle use. We argued that attitudinal differences concerning cycling between male and female might be the consequence and not only the cause of gender imbalance in bicycle use. In study 2, we thus investigated gender differences in attitudes towards cycling and cycling infrastructure, the purpose of cycling, risk perception, and exposure to severe crashes. We found gender differences in attitudes towards cycling to be small in terms of effect size or non-significant, with women having more positive attitudes in personal benefits rather than mobility benefits. Women reported gender-stereotyped reasons for cycling more than men, except for social activities. Also, women showed higher discomfort than men cycling in mixed traffic and higher

risk perception than men. Furthermore, men reported higher exposure to severe crashes than women. We contended that bicycle use and gender role could affect differences between male and female cyclists in perceptions, attitudes towards cycling, and cycling behaviours. In Study 3 we investigated gender differences in bicycle crashes, using routinely recorded crash data. We focused on characteristics related to the type of crashes (the type of collision and opponent vehicle), the infrastructure (road type and type of road segment), the environment (season, road surface condition and weather) and time (time of the day and day of the week). Results revealed that, compared to women, men were more likely to be involved in a crash regardless the age. Moreover, we found gender differences in terms of the type of road segment, type of opponent vehicle, type of manoeuvre of the opponent vehicle and of the cyclists, type of collision, time of the day, day of the week and season. Lastly, in Study 4 we aimed to investigate the role of attitudes, e-bike use, and perception of driving behaviour of motorists in predicting bicycle crash involvement and severity while controlling for socio-demographic factors, cycling levels, cycling environment, and purposes of cycling. Previous studies have revealed the relevance of e-bike use, perception of driving behaviour of motorists, and instrumental and affective factors in work and leisure journeys among regular cyclists. However, the importance of these factors as predictors of bicycle crash involvement and severity is less well-known. Using the generalised linear model, we found that both bicycle crash involvement and severity were related to lower age, being employed, using the bicycle for travelling to or from college/university, not using the bicycle for leisure/training, and using an e-bike. Bicycle crash severity was associated with lower affective attributes, higher instrumental attributes, and the perception of good driving behaviour of motorists. In the last chapter of the thesis, we discussed the theoretical and practical implication of our results.

# Summary

"When I see an adult on a bicycle,

I do not despair for the future of the human race."

**H.G. Wells**

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# Chapter 1

## 1. Introduction

### 1.1. Cycling and its benefits

Bicycling is an active mode of transportation that is associated with population-level health benefits (Götschi et al., 2016; Kelly et al., 2014). Furthermore, a bicycle, as an alternative to the automobile, holds the potential to reduce traffic congestion, air and noise pollution, and fossil fuel consumption (Macmillan et al., 2014; Xia et al, 2013). The following section will provide an extensive overview of research and studies that focused on highlighting the many benefits of using the bicycle.

**Figure 1**

*Cyclists during rush-hour in Utrecht*

#### 1.1.1. Benefits of cycling on physical health

Cycling appears to be a conceivably feasible, effective, and relatively inexpensive way to meet the World Health Organization recommended levels of physical activity for many populations. A large body of evidence suggests that cycling, as a form of physical activity, holds many benefits in terms of physical health (cf. Burke, 1992; Oja, 2011). Burke (1992), in a report commissioned by the U.S. Federal Highway Administration, reviewed a series of studies that supports the beneficial effect of physical activity, in particular regarding walking and cycling, on various elements of personal health (e.g. cardiovascular health, weight loss, ageing, osteoporosis, cholesterol, hypertension). The author also explains that although cycling entails a certain degree of risk (e.g. due to incurring in a crash), evidence supports a favourable risk/benefit ratio for regularly engaging in bicycling.

Historically, the first epidemiological studies linking physical activity to decreased risks of cardiovascular diseases and death are dated back to 1950s and focused mainly on work and organisational contexts (Morris et al., 1953; Taylor et al., 1962; Paffenbarger et al., 1971). More compelling evidence of the beneficial effects of physical activity on the cardiovascular system is presented in other studies. A study by Paffenbarger (1986), which followed more than 16.000 men for a time span of 25 years, revealed that who regularly practice physical activity had a reduced risk of myocardial infarction and death when compared with more sedentary individuals. This has been confirmed in another study (Leon et al., 1987) and in a review (Powell et al., 1987) published soon after. Commuting by bicycle was also found to bear statistically consistent improvements in cardiorespiratory responses and in metabolic response, with greater effects when compared to walking (Oja et al., 1991).

More recently, evidence of the benefits of cycling on physical health has been largely confirmed. A systematic review which aimed at assessing new studies focusing on cycling-specific health outcomes (Oja et al., 2011), demonstrated a consistent dose-response for improved function and health. Specifically, it has been shown that using the bicycle for commuting trips substantially improves the cardiorespiratory functioning of less physically active adults up to 30% (Hendriksen et al., 2000). To a lesser extent, improvements can be observed in medium and high-fitness adults as well. Other research showed a significant association between the reduction of all-cause mortality risk and daily cycling in a population of Chinese women (Matthews et al., 2007). Less than an hour per day of moderate-intensity cycling, compared with non-cycling, brings an all-cause mortality risk reduction of 20%, which increases up to 30% with 100 min of daily cycling. The same research indicated a cancer mortality risk reduction of 20% with 1h of daily cycling, which jumps to more than 40% with at least 100 minutes of moderate-intensity daily cycling. Hou et al. (2004) found that the risk of developing colon cancer diminishes as daily cycling increases. Authors pointed out that using the bicycle for at least 1h per day reduces such risk by around 20%, and by 40% with at least 90 min. The protective effect of cycling against cardiovascular diseases, in a dose-response effect, has been supported by Hoevenaar-Blom et al. (2011). Authors showed that pedalling for up to or more than 3.5 hours per week reduces such risk by about 20%, and if cycling is combined with other sports, the risk is reduced by almost 40%.

### 1.1.2. Benefits of cycling on mental health

Several studies have examined the relationship between physical activities, such as cycling and mental health. For instance, people participating in physical activity programs frequently show a reduction in depression and anxiety, and an enhanced sense of well-being (Burke, 1992). Evidence

also suggests that cycling could help people that have been diagnosed with schizophrenia in reducing their symptoms and experiencing higher levels of mental wellbeing even if results are not strong enough to draw a definitive conclusion (Gorczynski & Faulkner, 2010).

There is ample evidence supporting the beneficial effects of physical activity and, more specifically, cycling on the physiological adaptation to stress (Dishman & Jackson, 2006; Forcier et al., 2006; Sothmann et al., 1996). The cross-stressor adaptation hypothesis elaborated by Sothmann et al. (1996) states that physical activity allows to "train" the physiological response to stress exposure, reducing activation and recovery times. Two meta-analyses by Forcier et al., (2006) and by Dishman and Jackson (2006) agree that levels of physical activity are associated with a faster recovery after exposure to a source of stress. Still, conflicting results have been reported in the two meta-analyses with regards to stress reactivity.

Most of the current evidence supports the idea that cycling could have positive effects on people experiencing anxiety. This notion is supported by findings from De Moor et al. (2006) which showed that people that exercises more frequently tend to report fewer symptoms of anxiety. Goodwin (2003) found that who exercises regularly tends to be less at risk of panic attacks, social phobia and agoraphobia, controlling for socio-demographic characteristics and health-related issues. Two prospective longitudinal studies show further support. The first found that people who made at least three hours of vigorous exercise per week had a 53% decreased likelihood of developing anxiety disorders (Beard et al., 2007). The second study found that physical activity decreased the likelihood of developing anxiety disorders by 48% in a sample of young adults in Germany. Another important research by Wipfli et al. (2008) assessed only experimental randomised trial studies. Authors highlighted that people who were assigned to the physical activity condition reported significantly lower levels of anxiety compared to people in the control group—this particular study aided in establishing the causal relationship between beneficial effects of physical activity on anxiety symptoms.

Clear, strong and well-documented evidence supports the idea that cycling could have beneficial effects both in preventing and reducing symptoms related to depression. One prominent research by Larun et al. (2006) showed that, after controlling for age, gender, level of education, income, alcohol consumption, and other psychosocial factors, the risk of being diagnosed with depression decreased of 15-25% in psychically active participants. Cycling could have positive effects also in treating depression, as it has been shown by other authors (Conn, 2010; Ahn & Fedewa, 2011).

It has been suggested that cycling could have a significant effect on cognitive functions (i.e. perception, attention, learning capabilities, memory, speech, reasoning, and intellect) both in terms of development, for children and young adults, and retention, for the elderly population. In a meta-analysis investigating the effect of physical activity on cognitive functions in children and adolescents (Sibley & Etnier, 2003) results show different effect sizes according to the specific function: larger for perception, followed by intellect and learning capabilities and smaller for speech. Tomporowski et al. (2008), in a review about the relationship between regular physical activity and cognitive function, showed that children that do daily physical activity also performed better in school. About retaining cognitive functions of the elderly, a recent study suggested that therapy with a stationary bicycle may be feasible as well as effective for improving the cognitive function in elderly cancer patients (Miki et al., 2014). Results of a meta-analysis considering only prospective studies highlighted that people who exercise regularly have a reduced risk, by 35-38%, of showing a decline in cognitive functions later in life (Sofi et al., 2011). Further research suggests that physical activity can reduce cerebral arthropathy in Alzheimer patients and that among people with a cognitive deficit, the most physically active ones showed an increased volume of the hippocampus (Heyn et al., 2004).

### 1.1.3. Benefits of cycling for employees and organisations

Cycling also represents a cheap and effective way to cope with the sedentary lifestyle required by many modern workplaces. Studies suggested that benefits can be seen for firms and companies that incentivise employees to commute by bicycle. Commuting by bicycle is a healthy and relatively easy to incorporate in regular daily routines (Vuori et al., 1994; Hendriksen et al., 2000). Authors suggested that it is also a good opportunity for increased levels of physical activity in a large group of employees (Oja et al., 1998). In a cross-sectional study by Hendriksen et al. (2010), which followed 1236 employees for a one-year time span, it has been shown that the average absenteeism over the study year was shorter for cyclists than non-cyclists by more than one day. The cycling-to-work group included a higher proportion of employees that reported no sickness absence at all. Authors were also able to observe a dose-response relationship between cycling speed, total commuting distance and absenteeism. They concluded that not only cycling is associate with less absenteeism, but the more often people commute by bicycle and the longer the commuting distance, the less they called in sick.

Cycling home after a long day at work is an opportunity for employees to detach from work psychologically and to satisfy the psychological need for relatedness and competence (Feuerhahn et al., 2014). Evidence suggested that cycling to/from work is positively associated with employees' positive affects and significantly help them recover in the evening after the working day (Feuerhahn

et al., 2014). The study from Feuerhahn et al. (2014) found that employees who engaged in physical activities after work, such as cycling, were more likely to report positive affect in the evening. According to the effort-recovery model (Meijman et al., 1998), positive affect after the workday can be seen as a gain of affective resources that may be used immediately in the family and the next day when returning to work, potentially enhancing on-the-job performance such as creativity (Amabile et al., 2005). In fact, when exercising, people generally use different resources than those needed to perform at work, implying a cognitive distraction of job—related duties (Yeung, 1996). Previous evidence already suggested that engaging in regular physical activity (e.g. cycling) triggers physiological and psychological processes contributing to an increase in individuals' health and well—being (Brown, 1990; Wankel & Berger, 1990). A study using daily diary data further established that the amount of time spent on physical activities such as cycling is related to increased situational wellbeing before going to sleep in employees. In contrast, work-related activities were found to be negatively associated with situational wellbeing (Sonnentag, 2001).

## 1.2. Interventions aiming at promoting the use of bicycle

The evidence listed in the above chapters provides strong support for the promotion of cycling for multiple reasons. It is crucial to base current and future interventions on up-to-date evidence of the benefits of cycling. Promoting the use of the bicycle is thus seen as an essential strategy to improve citizens quality of life and reduce the adverse effects of the car-centric urban mobility plans and choices that were characteristics of previous decades (Nieuwenhuijsen & Khreis, 2016). The adverse effect includes sedentarism, ecological issues of air and noise pollution, greenhouse gas emissions and the loss of natural outdoor environments, but also to economic issues of space scarcity, congestion costs and financing infrastructure (Khreis et al., 2016; Marqués et al., 2015). Figure 2 shows an example of an advertising campaign aiming at increasing the saliency of the benefits of cycling. In order to develop effective policies and interventions, it is of utmost importance grounding on evidence regarding cyclists' attitudes and behaviours, identifying segments and homogeneous groups.

**Figure 2**

*Example of campaign-based intervention to increase the saliency of the benefits of cycling*


### 1.2.1. Cycling during the COVID-19 pandemic

"Install the antivirus" is one of the most famous slogans that characterised the “andràtuttinbici” communication campaign that has been launched in the city of Bologna, Italy, right after the COVID-19 national lockdown. The initiative has been promoted by the Municipal Bicycle Council to recount the advantages of active mobility during phase-2 of the coronavirus pandemic: cycling guarantees social distancing, it is good for health, strengthens the immune system and keeps the air clean. It also promotes life in the open air, gives more time free time and allows citizens to rebuild relationships broken by quarantine. Figure 3 shows a cyclist next to an “andràtuttinbici” advertising campaign billboard.

**Figure 3**

*A cyclist in the city of Bologna and a poster of the communication campaign #andràtuttinbici*


The advertising campaign is only the beginning of a project that wants to go further, thanks to the financial contributions of about 400 people on the GoFundMe platform. The objective is to bring the campaign to media (TV and radio stations) and companies in the city of Bologna. The initiative will continue with the development of a web-based platform, which aims to support and strengthen the habit of those who have decided to ride a bike for the first time. The platform will, again, target the metropolitan city area of Bologna, but developers aim at extending it to other cities.

In the metropolitan city area of Bologna, before the COVID-19 pandemic, around 850,000 daily trips were made using local public transport. With the reopening of activities, there is the risk that a considerable number of these people would decide to use a car. The Municipal Bicycle Council of the Municipality of Bologna has immediately taken action, both at the local and national level, together with other realities active in the world of urban cycling (e.g. Fiab, Salvaiciciclisti, Bikeitalia.it), to tackle the critical issues that will arise from the post-virus restart on the sustainable mobility front. The goal of the campaign is to explain that using the bike, especially for trips under 5-10 km, is not only possible, convenient, and very cheap, but it also has benefits in terms of personal health. Furthermore, cycling allows to maintain social distancing, thus reducing the probability of COVID-19 contagion, and it is deemed to be one the safest sustainable means of transportation after quarantine. Figure 4 shows the billboard emphasising the advantages of using the bicycle against COVID-19.

**Figure 4**

*Advertising poster part of a campaign-based intervention to increase the use of bicycle in the city of Bologna, Italy: "Install the antivirus, choose the bike"*


## 1.3. Cycling safety

Despite the great value of choosing the bicycle as primary means of transport and the beneficial effects in terms of personal and public health, cycling still entails a certain degree of risks. As a matter of fact, cyclists suffer a disproportionate share of serious injuries and fatalities, and indeed, in recent years, that disadvantage has been growing. The research established that safety considerations represent a significant barrier to bicycle use and promotion (Jacobsen & Rutter, 2012). Perceived crash risk was also found to be one of the most relevant factors discouraging cycling (Useche, Montoro, Sanmartin et al., 2019).

The number of bicycle fatalities varies substantially between countries. However, while cyclist prevalence explains some of the variations, there are some indications that the mileage travelled by bike is not the only factor that influences death rates (Steriu, 2012a; Steriu, 2012b). Substantial improvements have been made to increase road safety in recent years. Nevertheless, cyclists' fatalities and injuries remain a severe social problem. In the first decade of the 21st century, the percentages of cyclist fatalities in the total number of road accident fatalities in EU has been approximatively stable (6.3% in 2001 and 6.8% in 2010) while the percentages of car occupant fatalities in the total number of road accident fatalities have decreased considerably (54% in 2001 and 48% in 2010). Indeed, in many countries, cyclists account for a growing share of persons injured in traffic accidents. According to data provided by the European Commission (ERSO, 2016), 2143 bicyclists died in road accidents, in Europe, in 2012. Although the total number of cycling fatalities

did not increase significantly from 2004 to 2013, the proportion of cyclist fatalities with reference to overall road fatalities showed a growing trend (ERSO, 2016). The majority (52%) of cyclist deaths in European roads between 2011 and 2013 had passenger cars as opponent vehicles, whereas 24% were against goods vehicles or buses/coaches (Adminaite et al., 2015). Collisions with motorised vehicles account for the highest proportion of cyclist deaths in the EU, on average 74% of the deaths between 2008 and 2010 (52% collisions with cars or taxis, 22% collisions with goods or public transport vehicles). Looking at data from the year 2014, the trend continued. A total of 2112 cyclists have been involved in fatal crashes in EU countries (ERSO, 2016) which means the 8.1% of total road deaths, representing a 0.3% increase in respect to the previous year. Recent statistics support that the share of bicyclist fatalities on the overall road fatalities in EU countries has been growing (Evgenikos et al., 2016). Statistics from the Road Safety Annual Report (Janstrup, 2017) further confirms the issue, highlighting that less success is achieved in saving lives among vulnerable road users than amongst motorised vehicles drivers. Reductions in deaths of pedestrians and cyclists have levelled-off and increases have been recorded since 2009. Most recent statistics on road accidents still highlights that the growing share of cyclists losing their lives in road crashes is of particular concerns (Janstrup, 2017). For instance, figures from the UK show a negative trend in cyclist safety. In the UK, the number of pedal cyclists who were seriously injured in 2011 rose by 4 per cent to 3,222 in 2012; the total number of pedal cyclists killed or seriously injured rose by 5 per cent between 2011 and 2012 and now stands at 32 per cent more than the 2005-09 average. The number of pedal cyclists killed or seriously injured per million miles cycled has risen by 18 per cent from the 2005-09 average. To what regards Italy, according to the data provided by the Italian National Institute of Statistics (ISTAT, 2015), 575,093 road accidents occurred in the timeframe ranging from 2011 to 2013, on the Italian road network. Of these, 49,621 road accidents involved at least one injured or killed cyclist. The number of bicycle fatalities during this period was 823 (1.7% of roads accidents involving at least one injured or killed cyclist).

In the domain of traffic safety, cyclists are often referred to as Vulnerable Road Users (VRUs) or minority road users (Prati, Marín Puchades & Pietrantoni, 2017). One of the first times that the definition of VRUs has been provided to address cyclists in an official document can probably be traced back to 1998 (OCDE/OECD, 1998). The definition, which can supposedly be dated even further back in time, is nowadays widely adopted in transport and traffic-related research. The primary reason why cyclists are characterised as VRUs is that they lack physical protection from other motorised traffic (OCDE/OECD, 1998). Cyclists also have a considerably lower mass and proceed at lower speeds than the vast majority of motorised vehicles (Wegman et al., 2012). Haworth and Debnath (2013) have defined cyclists as minority road users for similar reasons (i.e. lower mass,

less conspicuity, lack of physical protection, less stability, and more affected by road surface irregularities). Prati, Marìn Puchades and Pietrantoni (2017) further contributed to developing this definition in a recent article. Authors proposed a conceptualisation of cyclists as minority road users, as opposed to vulnerable road users, basing not only on the lack of physical protection (which is the emblematic characteristic of vulnerable road users) but on the social and cultural factors that shape the membership within the group of cyclists as well. In their study, the definition of cyclists a minority was based on eight dimensions (i.e. power, number, distinctiveness, social category, group context, dispositions, being the source and target of behaviour) taken from the social-psychology conceptualisation of majority and minority groups by Seyranian et al. (2008). Authors gathered evidence that cyclists tend not to be identified and considered equally as other road users, tend to be numerically small, constitute a social category, report negative social, political, or economic circumstances, and are the source of specific behaviours (e.g. cycling advocacy and cycle activism) and target of behaviours (e.g. aggression, negative attitudes, and warnings). It is though essential to mention that perceptions of cyclists or cycling identities may vary according to the specific country, in which there could be different cycling levels and a different cycling culture (Prati, Marìn Puchades & Pietrantoni, 2017). The societal acceptance of cycling by a specific community plays a significant role (Willis et al., 2015). Different countries, communities or even groups generally show differences in social acceptance, subjective norms, and attitudes towards cycling, which are core elements of bicycling culture.

### 1.3.1. The cost of cycling safety

According to the European White Paper on Transport (European Commission, 2011), an integral part of urban mobility and infrastructure design should become the promotion of cycling. However, along with the promotion of cycling, particular attention should be given to cyclists as vulnerable users through safer infrastructure and vehicle technologies.

A cost-benefit analysis carried out in the Horizon 2020 PROMISING (2001) project has shown that the crash costs of cycling are higher than those of car driving; however, the total costs of cycling, including air pollution, traffic noise, and savings from reduced absence from work, are lower than those of driving a car. Other authors pinpointed that using the bicycle as primary means of transportation is related to a significant reduction of transportation costs for users, and it also brings many macro-economic benefits for countries (cf. Useche, Montoro, Sanmartin et al., 2019; Fishman et al., 2015). Cycling safety research should focus on reducing the crash costs of cycling. Human Factors and Traffic Psychology research results should help reduce bicycle crashes. In the cases of

cyclists' crashes with motorised vehicles, inattention, or failure to notice the cyclist, is a frequently reported contributing factor.

## 1.4. The role of Traffic Psychology

Psychology and, most precisely, the study of human behaviour is one of the most crucial elements for preventing traffic injuries (Evans, 2004; Sleet et al., 2011) and fostering public physical and mental health. By fostering public health, in the context of traffic psychology, we mean investigating antecedents and linking consequences of behaviours that are detrimental to the population health levels and at the same time antecedents of behaviours that can have positive effects on the population health levels. This is a topic of pivotal importance because it can allow finding evidence-based means to reduce adverse behaviours and effectively fostering behaviours that lead to a positive health effect. Previous literature about human factors, engineering and psychology, has shown a tightly entangle connection between human behaviour, the environment, the social context and technology to enhance public health and safety (Fuller & Santos, 2002; Summala, 2005). Whereas traffic psychologists have been notable contributors to understanding behavioural and social causes of traffic crashes and injuries (Evans, 2004), in many European countries municipalities, public bodies and policymakers are still under-recognising and consequently under-utilising information provided by traffic psychologists (Sleet et al., 2011). Under-funding is as well a problem in the field, which is luckily improving in Europe with recent initiatives and investments through the Horizon 2020 framework program and the soon to be activated Horizon Europe framework program.

To tackle the challenges of making modern road environment safer, reduce pollution, increase the quality of life in urban contexts and ultimately improve publics' physical and mental health we need the joint effort of trans-disciplinary teams with expertise in engineering, biology, medicine and equally importantly psychology and human factors (Sleet et al., 2011). Improving road safety, nowadays more than ever, demand a shift in how these disciplines think about risks related to the traffic environment, personal and public health behaviours, and the value of prevention and of prompting behavioural changes in citizens. Behavioural changes are in fact required to reduce traffic injuries and foster the use of sustainable means of transportation, but it will require even more in-depth and extensive research, a considerable amount of time, professional collaboration and investments. Sleet at al. (2011) perceptively pointed out that literature on public health show examples of effective behaviour change interventions aimed to improve health. Changes in entrenched behaviours are possible and can be achieved through joint actions of individuals and communities at many levels. The authors mention the example of smoking tobacco, which was once considered a harmless habit and often advised by physicians as a way to reduce stress. With growing

empirical evidence on the risks tied to tobacco use, the public began viewing smoking negatively, tobacco control became a significant health goal, and smoking declined dramatically. Similar changes are needed in the context of traffic, for example, to reduce the use of polluting vehicles and at the same time fostering safe behaviours, ultimately reducing the occurrence of traffic crashes. Credit to Sleet et al. (2011) for listing the major ways in which traffic psychologists and health experts can contribute to prompting such shift. Among them, the most relevant in the context of the current project are:

- to study road users' behaviour with the purpose to identify which are the most relevant risk factors in relation to traffic crashes and injuries;
- to produce evidence on behavioural determinants of traffic crashes and their associated psychological consequences;
- using psychological techniques and tools in safety audits to identify hazardous and unsafe road environments;
- employ up-to-date evaluation techniques to appraise the impact of road safety programs and interventions;
- applying behavioural theory to design interventions that influence policymakers to protect road users from traffic injury;
- disseminating critical behavioural research in traffic safety to public health practitioners and in key public health journals and books.

### 1.1. Objective of the present work

The research described in the previous sections extensively justify the importance of promoting the use of the bicycle as the primary mean of transportation on the one hand, and addressing possible downsides, which are mainly related to safety, on the other hand. To do so, from a traffic psychology perspective, we are primarily interested in contributing to increasing theoretical knowledge about psychosocial factors and behaviours related to cycling use and possible contributors to cycling crashes.

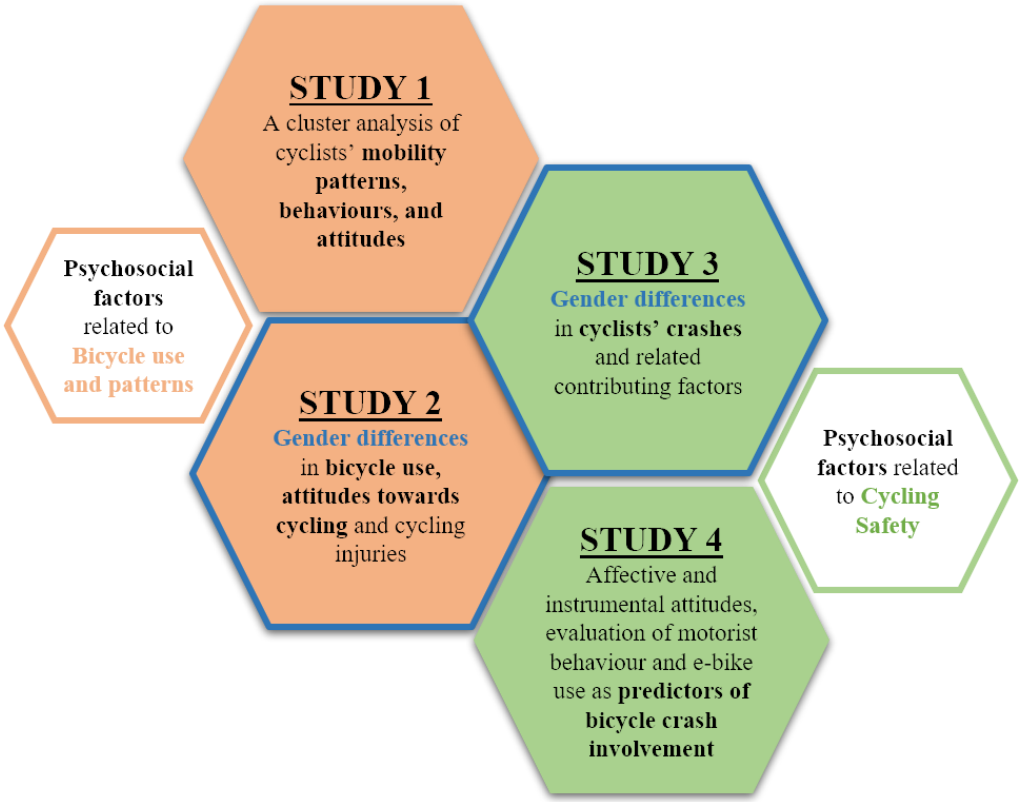
Support for this objective can be found in the current literature. Authors, for instance, stated that even though previous studies focused on the influence of attitudes on road transport behaviour, there is still a lack of studies focusing specifically on cycling (Heinen et al., 2010). Additionally, almost all studies focused on the general attitude toward transport modes and not specifically on the relation between different attitudes and bicycle use, suggesting that psychological-related factors associate to bicycle use, patterns and riding behaviour need to be further investigated (Heinen et al.,

2010). To achieve significant results in the long term, it is also crucial to address inequalities related to cycling use. In the literature, it is, in fact, possible to find growing support for the idea that the benefits related to the use of the bicycle are not equally distributed among the population (Heinen et al., 2010). Since cycling is strongly linked to social factors, gender differences appear to be particularly worthy of attention. To what regards cycling safety issue, authors highlighted that it is a significant contributor to raising barriers to cycling and its promotion and researchers have begun to focus their attention on cyclists' accidents and their contributing factors (Jacobsen & Rutter, 2012; Schepers, Hagenzieker, Methorst et al., 2014; Prati, Marìn Puchades, De Angelis et al., 2018). Psychosocial factors such as instrumental and affective attitudes, perception of motorist behaviour, and determinants of work and leisure journeys among regular cyclists possibly play an essential role. However, the importance of these factors as predictors of bicycle crash involvement and severity is less well-known. A closer look at the literature reveals that gender could play a role in bicycle crash involvement as well. The relationship between gender, crash involvement rate and motorists behaviour has been previously investigated (e.g. Al-Balbissi, 2003; Cordellieri et al., 2016; Factor et al., 2008; Massie et al., 1995; Pulido et al., 2016; Rhodes & Pivik, 2011; Santamariña-Rubio et al., 2014; Tom & Granie, 2011; Williams & Shabanova, 2003). However, to our knowledge, no studies would focus specifically on cyclists.

The aim of this thesis addresses this matter. The work can be broadly separated into two parts: the first focuses on psychosocial factors (e.g. attitudes, motivations) and behaviours in relation to the use of the bicycle. The second part focuses instead on deepening the understanding of the interplay between such factors and bicyclists' crash involvement and severity. Figure 5 depicts the relationship between the studies included in the present work. Increasing knowledge on the above-mentioned topic could ultimately contribute to the development of effective policies and interventions to increase levels of cycling and cycling safety.

**Figure 5**

*Structure of the present thesis*




## 1.2. Psychosocial factors related to cycling use and cycling safety

In this section, we review the literature in relation to the objectives of the thesis. The major areas of research are explained, and theoretical gaps are highlighted.

### 1.2.1. Cycling patterns

One broad area of research focuses on cycling patterns or, in other words, how and how much people use the bicycle. We here summarise the most relevant variables on the matter.

#### Cycling Frequency

Cycling, or riding, frequency is one of the most often considered variables in cycling studies. It is possible to find many studies in which cyclists have been characterised basing on their riding frequency (Bergström & Magnusson, 2003; Heinen et al., 2011b; Larsen & El-Geneidy, 2011; Winters et al., 2011). It has been shown that subgroups of cyclists, based on their stated riding frequency, significantly differ from one to another (Ahmed et al., 2017; Heinen et al., 2011a). Ahmed et al. (2017) found that weather conditions influenced the decision to whether cycle or not of commuter cyclists who do not plan their behaviour in advance. Moreover, the authors found that cycling frequency, for commuters, was affected by the presence of off-road paths and favourable

weather. Similarly, Heinen et al. (2011a) found that based on riding frequency, two groups of part-time cyclists exist: occasional cyclists and frequent cyclists. Favourable weather conditions influenced more occasional cyclists than frequent cyclists. In contrast, frequent cyclists were discouraged from cycling by more practical reasons such as wind speed and the need to be at multiple locations. The categorisation of cyclists based on riding frequency aided to identify differences in mode choice between seasons (Bergström & Magnusson, 2003) and influenced the likelihood to ride (Winters et al., 2011).

**Cycling trip purpose / Cycling motivation**

To identify different typologies of cyclists, previous authors frequently considered the motivation to cycle as an important factor. In research by Streit et al., (2014) trip diaries were used to group cyclists by riding frequency and reason why they use the bicycle (i.e. leisure vs commuting). An akin approach can be found in other studies (Heinen et al., 2011a; Dill & Voros 2007). Significant results were found when using cycling motivation (commuting versus non-commuting) as segmentation criteria (Kroesen & Handy, 2014; Rondinella, 2015). Clustering cyclists based on cycling trip purpose helped to shed light on habits and patterns of cyclists and to understand that recreation or sport seems more relevant than commuting as cycling trip purpose (Burbidge & Goulias, 2009; Moudon et al., 2005; Sener et al., 2009).

**Modal split**

Modal split is another critical factor in research when it comes to assessing mobility patterns and changes over time or the effectiveness of interventions in promoting a modal shift towards active mobility (Barberan & Monzon, 2016; Rayaprolu et al., 2018; Song et al., 2017). Modal split can otherwise be considered as the percentage of use of one specific mean of transportation on the total time spent in participating in traffic. Authors showed that the modal split is a relevant factor for identifying cyclists' habits. Barberan & Monzon (2016) showed that people prefer to drive their cars to commute to work and almost equally to walk and cycle to their place of study. Jensen (1999) categorised cyclists according to their inclination on whether using public transport or the bicycle. He distinguished three categories: the "cyclists/public transport users of heart" which cycle for the enjoyment of the experience and decide not to own a car; the "cyclists/public transport users of convenience" which cycle because it is the most convenient mode; the "cyclists/public transport users of necessity" which cycle because they cannot afford a car. These categories are useful to structure modal split as a function of choice, whether from principle or utility or of mode constraints.

### 1.2.2. Cyclists' characteristics

It would be impossible to achieve the proposed objectives without taking into account cyclists' psychosocial characteristics. Here we present the most relevant variables used in research to investigate cyclists' psychosocial characteristics.

#### Culture and Gender

Numerous studies focused on investigating the socio-cultural characteristics of cyclists. Gender differences in cycling, for instance, have been identified in previous studies (e.g. Garrard et al., 2012; Heesch et al., 2012; Wittmann et al., 2015). Authors contributed to highlighting significant differences in terms of perceptions, attitudes, and behaviours. The country of residence is also an essential factor when looking at cycling patterns. There are substantial historical differences in the share of cycling between European countries, for example, The Netherlands, Sweden and Hungary cycling share differ substantially from Italy, Spain and U.K, according to recent figures (European Commission, 2014). In Italy, about 6% of respondents mentioned the bicycle as the mode of transport most often used, while in the Netherlands this percentage rises up to 36%.

For the context of the present thesis, it is worth to mention gender differences and related cultural and social factors briefly. Nowadays, sexism and discrimination still represent relevant issues in many societies, raising concerns about what are the consequences of patriarchy on women's lives, what are the resources to which women do not have adequate access and what are the disadvantages in personal, relational and social terms (Pacilli, 2020). According to the Global Gender Gap report 2020, projecting current trends, the overall global gender gap will close in 99.5 years, which lowers to 54 if considering only the Western European countries (Crotti et al., 2020). The report particularly highlights that women's presence in the labour market is still stalling (i.e. 55% of adult women versus 78% of men) and financial disparities are slightly larger, for many countries, if compared to the previous year. Gender wage gap amounts to over 40% and the income gap to over 50% (Crotti et al., 2020). Regarding theoretical explanations for gender-related differences, authors tethered to the concept of Psychological Essentialism (Ortony, 1989) and Gender Essentialism (Pacilli, 2020). Essentialism can be described as the tendency to think that people belonging to the same category have the same qualities and characteristics, perceiving the essence of a social category as immutable from a historical and cultural point of view. In western countries, practicing physical activity, sports and in particular cycling, can be considered a health-related behaviour. Such activities can be counted among the practices used by men and women to differentiate themselves: they become a way of demonstrating their adherence to a traditional vision of masculinity (Pacilli, 2020). Studies showed gender influencing the use of the bicycle as a means of transport (Bergström & Magnusson, 2003;

Heinen et al., 2010; Prati, 2018) and the reason to use the bicycle. Women tend to cycle mostly for non-commuting trips such as travel with children and to carry shopping and other goods (Pucher & Buehler, 2012). Authors argued that gender identities could influence political and strategic choices related to sustainable transport (Kronsell et al., 2020). Kronsell et al., (2020) contributed to understanding how, for example, gendered norms find expression in transport policy and planning. Results of their study indicated that the inclusion of sustainability in transport policies and planning is related to the presence of masculine and feminine norms rather than actual male and female. Other authors, addressing gender differences in mobility patterns in two Asian cities found such difference to be worrisomely similar to differences between dwellers of wealthy and poor areas (Tran & Schlyter, 2010). Specifically, they found women to be more likely to women walk and men to use motorised vehicles. Tran and Schlyter (2010) also supported preliminary findings suggesting that women mobility patterns, despite their high participation in the labour market, are still related to their stereotypical gender role of household carers. According to this line of reasoning, it is of crucial importance to investigate gender differences related to cycling use and safety.

### Attitudes towards cycling

Attitudes toward cycling have been occasionally considered in previous studies but have been consistently found to influence bicycle use, mode choice, and purpose for cycling (Gatersleben & Appleton, 2007; Gatersleben & Uzzell, 2007; Heinen et al., 2011b; Swiers et al., 2017). Heinen et al. (2011b) reported that when commuters find cycling to be comfortable, flexible, and time-saving, they were more prone to cycle to work. Similar results were found for individuals who considered cycling environmentally friendly, healthy and mentally relaxing (Heinen et al., 2011b). It has been argued that the combination of motivational and attitudinal factors affecting travel choice for distinct groups of people is often neglected when it comes to cycling research. Some authors, for example, provided evidence that albeit land use characteristics have some significance in explaining travel behaviour, individual attitudes are often more strongly associated with travel behaviour than land-use policies which promote higher densities (Handy et al., 2005; Mercado & Páez, 2009; Susilo & Maat, 2007; Susilo & Waygood, 2012). It has been claimed that land-use policies promoting mixed-use and higher density developments may not have an appreciable effect on travel behaviour unless actions are taken to prompt a change in individuals' attitudes (Bagley & Mokhtarian, 2002; Susilo et al., 2010). Further studies investigated the importance of assessing how cycling is socially viewed, considering which are the values linked to cycling, its image, and the aspects perceived as requirements for being able to cycle appropriately by the population (Aldred & Jungnickel, 2014). A report from Burke (1992) mentioned that individuals found cycling to give them a sense of health, independence, and

enjoyment. Bicycling was also associated with economy, cleanliness, freedom, and " doing your own thing".

Attitudes towards cycling have been correlated to many different features, such as amusement, relax, comfort, convenience, usefulness, accident risk, environmental benefits, health and flexibility (Barberan & Monzon, 2016). Those attitudes have been grouped by authors trying to measure attitudes (Fernández-Heredia, 2016; Muñoz et al. 2016). Anable and Gatersleben (2005) addressed the evaluations that the person holds regarding cycling as a transportation mode and how they impact on mobility choices. In their work, attitudes were grouped into two categories: hedonic and instrumental attitudes. Hedonic attitudes, initially addressed as affective, refer to the positive emotions experienced while cycling such as excitement, pleasure, and control. The majority of studies that focused on appraising the affective experience of travel included the participants' perception of stress, especially concerning commuting trips (Koslowsky, 1997; Gulian et al., 1990). Instrumental attitudes refer instead to the utility or functionality of cycling (e. g. predictability, safety, and convenience). Those attitudes have been investigated to understand their impact on people's mobility choices (Bamberg and Schmidt, 2001; Van Lange et al., 1998). To summarise, it is possible to group attitudes towards the benefits of cycling such as personal health (Woodcock et al., 2014; Useche, Montoro, Sanmartin et al., 2019), environmental benefits (Karanikola et al., 2018; Pucher & Buhehler, 2017), low-cost (de Nazelle et al., 2011; Macmillan et al., 2014) and flexibility of cycling under the broad category benefits of cycling. Stinson and Bhat (2004) showed that cyclists who considered cycling as "flexible" and "with predictable travel time" were more likely to use the bicycle as the primary mode of transportation. Support for grouping such attitudes in one factor is provided by the study from Heinen et al. (2011b) in which authors, using factor analysis on bicycle attitudinal characteristics, addressed health benefits, environmental benefits, and economic benefits under the category called "awareness". To our knowledge, no studies in literature ever attempted to profile cyclists in terms of attitudes with a multi-country European sample.

### 1.2.3. Cycling safety and risk perception

Another relevant topic in traffic psychology research is related to road users' perceptions of risks, which have been found to influence risky behaviours significantly. Specifically, risk perception showed a positive correlation with safety outcomes by behavioural adaptation, both theoretically and empirically (Ba et al., 2016; Koornstra, 2009). It has also been found to influence cycling attitudes and adoption (Ul-Abdin, 2019). Risk perception should be considered as a cognitive construct of primary importance when investigating road users' behaviour (Puchades et al., 2018) and its dependency on other internal (e.g. fear, sensation seeking) and external factors (e.g. other road users'

behaviours, quality and provision of dedicated infrastructure) should be taken into account (Koornstra, 2009; Manton et al., 2016; Heesch et al., 2012). Some authors highlighted that there is still lack of research addressing the influence of those elements on cycling adoption and cyclists' safety outcomes (Puchades et al., 2018).

### Comparative risk perception

The perceived risk associated with cycling is an important topic in literature, and as we previously mentioned, cycling is associated with safety concerns (Heinen et al., 2010; Schepers, Hagenzieker, Methorst et al., 2014; Wegman et al., 2012). The characterisation of bicyclists as VRUs is, in fact, crucial to this matter (Manton et al., 2016; Siman-Tov et al., 2012), as cycling is associated with a higher risk of injury than travelling by car or other means of transportation (Heinen & Handy, 2012; Wegman et al., 2012). High-risk perception is identified as one of the significant psychosocial barriers that prevent people to cycle more (Koglin & Rye, 2014; Pucher & Dijkstra, 2000) in many different countries (Feleke et al., 2018). Specifically, the risk of being involved in traffic collisions is found to be one of the most frequently mentioned hindrance to cycling (Parkin et al., 2007; Heinen et al., 2010), including among regular cyclists (Bauman et al., 2008). Previous research has highlighted that when people are inquired to consider their chances of experiencing certain illnesses or accidents, it is important to address the unrealistic optimism bias (Friedman, 2011) thus assessing risk perception in comparison to an average peer of the same age and gender. The unrealistic optimism bias has been conceptualised as the tendency of people to overestimate the risk of others and underestimate the same risk for oneself (Weinstein, 1980). When assessing risk perception, other studies (e.g. Martha & Delhomme, 2009; Schwarzer, 1999) suggested highlighting the difference between the perceived risk for oneself (personal risk perception) and the perceived risk for others (general risk perception). Moreover, it appears that studying people's subjective evaluations regarding safety and comparative risk is remarkably relevant for increasing cycling safety and bicycle adoption, especially because perceived risk has been found to influence cyclists decisions to shift to other modes or even avoid trips (Heinen et al., 2010).

### Quality and provision of cycling related infrastructure

An influential factor connected to cycling risk perception is the provision and quality of cycling infrastructure and, specifically, their evaluation by road users. How the built environment is perceived may have an impact on whether a cyclist feels safe or at risk and has often been considered in the literature. Manton et al. (2016) presented a broad overview of critical infrastructural and traffic factors affecting cyclists' risk perception. These include the presence of cycling facilities, driving lane width, and pavement surface (Bill et al., 2015; Lawson et al., 2013).

### Cycling in mixed traffic

When it comes to promoting cycling and identifying measures to make cycling safer, an interesting amount of research has focused on the impact of the perceived discomfort while cycling on roads with mixed traffic and its relationship with perceived safety. It has been determined that, on the one hand, cyclists experience a higher feeling of safety on roads with physical separation from motorised vehicle traffic and, on the other hand, feeling to be most at risk on roads with mixed traffic (Heinen et al., 2010; Jensen et al., 2007). Major streets with shared lanes are associated with greater perceived risk (Winters et al., 2011).

### Motorised vehicle drivers' behaviour

The behaviour of private vehicle/truck drivers and its evaluation from the cyclists' point of view is another dimension that received particular attention in the field of cycling safety and promotion of cycling. From a social psychology perspective, research has shown that bicycle-motorised vehicles interactions contribute to rising concerns. For instance, cyclists frequently report being abused and harassed by drivers (Heesch et al., 2012; O'Connor & Brown, 2010). Other studies showed that cyclists' occupancy of the road is often considered bothersome by both professional and domestic drivers (Basford et al., 2002). Motorised vehicles divers generally have low opinions of cyclists and are inclined to criticise them for relatively minor matters while overlooking or excusing other motorised vehicle drivers' transgressions. Moreover, it is particularly interesting to note that cyclists' risk perception and safety concerns were found to be intensified by reported aggressive driving and features of motorists' behaviour (Bauman et al., 2008). To our knowledge, no studies focussed on assessing differences in the evaluation of motorist behaviours between groups of cyclists.

# Chapter 2

## 2. Behavioural and psychosocial patterns of European cyclists

Previous authors focused on cyclists' patterns and profiles to provide deeper insights into their behaviour and characteristics (Ahmed et al., 2017). Cycling patterns can be considered intrinsic lifestyle choices (Gatersleben & Appleton, 2007; Heinen et al., 2011a) and can be influenced by a range of factors, including socio-demographics and psychosocial ones. Identifying cycling patterns could help to discern which type of cyclists will likely be affected by specific interventions through assessing respondents' answers about motivators, deterrents, and infrastructure preferences.

### 2.1. STUDY 1: A cluster analysis of cyclists' mobility patterns, behaviours, and attitudes

Various studies focused on identifying segments of cyclists to discern differences in the needs and preferences regarding the use of such mode of transport. Clustering cyclists has been proved as an effective strategy to identify meaningful differences in patterns and behaviours (Ahmed et al., 2017; Félix et al., 2017) and develop typologies useful to understand variations and target policies towards the identified groups (Chaloux & El-Geneidy, 2019). Félix et al. (2017) published a systematic literature review that assessed studies that categorised cyclists' through different methods and compared the obtained cyclists' categories. Limitations in the current literature have been identified: first of all, considered studies focused on one single city or country, thus not allowing to profile groups in terms of countries and identify meaningful cross-boarders differences. This issue is heightened by the fact that studies in different countries use different approaches to segmentation (i.e. "Top-Down", e.g. a priori expert judgment or rule-based classification, versus "Bottom-Up", e.g. using respondents' data to perform cluster or factorial analysis). Secondly, there is still needed to explore motivators, deterrents, and attitudes when profiling homogeneous groups of cyclists. Heinen et al. (2011b) indicated that attitudes toward cycling have a relatively strong impact on the choice to commute by bicycle and suggested that psychological-related factors should receive more attention.

Profiling clusters of cyclists has been found to provide a meaningful understanding of their behaviour and characteristics (Ahmed et al., 2017; Kroesen & Handy, 2014). Cycling motives and frequency (i.e. cycling patterns) can be considered intrinsic lifestyle choices (Gatersleben & Appleton, 2007; Heinen et al., 2011a) and can be affected by a wide range of factors including socio-demographics and psychosocial ones. It is possible to find examples of authors that attempted to cluster their study population into groups according, for instance, to 'cycling frequency', 'cycling distance' and 'travel planning behaviour'. This allowed to increase knowledge regarding commuters'

cycling behaviour and specifically to understand how various factors relate to different types of commuter cyclists' riding decisions (Ahmed et al., 2017). Damant-Sirois et al., (2014) revealed four distinct cyclist typologies: "dedicated cyclists", "path-using cyclists", "fairweather utilitarians", and "leisure cyclists". The authors distinguished which type of cyclists will likely be affected by specific interventions through assessing respondents' answers about motivators, deterrents, and infrastructure preferences. Their work suggests that building a network which is customised according to different cyclist types preferences and needs, differently emphasising its convenience, flexibility, and speed, can be an effective strategy to increase cycling mode share and frequency among the various groups.

Furthermore, research in the field of marketing pinpointed that addressing the average consumer, or in the context of the present study the "average cyclist", is of little use in terms of research impact. It is in lieu more effective, to identify groups of people which can be separately addressed because they are motivated by different factors and are affected in different ways by policies and interventions (Anable, 2005).

Based on the above considerations, the Study 1 aimed to address the research gap previously highlighted in the literature, explicitly identifying naturally occurring subgroups in a population of cyclists in six different European countries (U.K., The Netherlands, Sweden, Hungary, Italy, and Spain). To our knowledge, there are no previous studies that focused on profiling clusters of cyclists according to socio-demographic and psychological-related factors such as attitudes towards cycling. Six European countries were selected according to two main criteria: to have countries with diverse cycling mode share and to obtain a balanced overview of E.U. geographical areas: Northern Europe (U.K. and Sweden); Western Europe (The Netherlands); Eastern Europe (Hungary); Southern Europe (Italy and Spain). According to the most recent aggregated data, the E.U. average cycling mode share is 8% while it substantially differs in each selected country (European Commission, 2014). Table 1 displays the average cycling modal share for each country selected in the present study.

Table 1

*Cycling Modal Share of the selected countries*

| | Average Cycling Modal Share |
|---|---|
| U. K. | 3% |
| Spain | 3% |
| Italy | 6% |
| Sweden | 17% |
| Hungary | 22% |
| The Netherlands | 36% |

### 2.1.1. Materials and methods

#### Procedure

The survey was administered between 27th January and 5th February 2018, to an 'online panel' of respondents in six countries (Hungary, Italy, Spain, Sweden, The Netherlands, United Kingdom) who had previously agreed to take part in data collection. The online panel was bought from Qa survey company, a research-related service provider firm based in the U.K. The survey was administered to an online panel of respondents from six European countries (Sweden, Netherlands, United Kingdom, Hungary, Italy, and Spain). Participants are individuals that have agreed to take part in surveys and inquiries on a regular basis and are registered to a web-based platform to do so. Panellists receive some form of rewards from the company that manages the panel for carrying out surveys, typically in the form of points or vouchers that can be exchanged for goods. Other reasons often cited include, ‘‘curiosity,’’ ‘‘fun,’’ and improving ‘‘products/services’’ (Callegaro et al., 2014). Online panels hold a considerable amount of information on their panellists (i.e. demographic data) which keep regularly updated. This allows the company to target surveys at specific groups and obtaining a specific sample, such as a nationally representative sample or a female-only sample. In the context of the present thesis, the sample within each country was required to meet the following criteria to ensure a wide range of user groups and to ensure representation from segments that are often underrepresented (e.g., female and older cyclists): (a) all respondents must make on average at least one cycle trip per month; (b) at least 50% of respondents must be regular cyclists (i.e., make on average two cycle trips per week), (c) at least 30% of the sample must be female, (d) at least 10% of the sample must be aged 50 + years, and (e) age equal to or higher than 18 years. Characteristics of participants that accepted the invitation to complete the survey were checked to ensure that there was no over- or under-recruitment of specific categories of the population. We excluded from analysis data of participants who filled out the questionnaire in a time shorter than the pre-established limit, and those who reported the same values within a whole scale. In order to assess whether there were

significant differences between young and elderly cyclists, and between male and female cyclists, it was crucial to gather a sample which included participants with those characteristics. The average completion time was around 35 minutes.

A pilot version of the questionnaire was administered to 60 participants, equally distributed between The Netherlands and the United Kingdom. After carefully checking the pilot data, the questionnaire was updated. Items which produced anomalous replies were refined with more comprehensible and less equivocating wording. Due to this change, pilot survey data have not been included in the final dataset. The finalised version of the questionnaire was translated, sense checked by native speakers, uploaded to the custom online survey platform, and administered to participants.

**Data and Participants**

A total of 2389 participants completed the questionnaire. Of these, 1171 (49.1%) were male, 1210 (50.6%) were female and 8 (0.3%) identified themselves as transgender. The sample of transgender participants was too small to be comparable with the other two categories. Thus it was not included in the subsequent analyses, leaving a sample of 2381 cyclists. Participants are relatively equally distributed across countries (United Kingdom: n = 396; The Netherlands: n = 395; Sweden: n = 392; Hungary: n = 399; Italy: n = 403; Spain: n = 396). The age of the participants ranged from 18 to 86 years. The mean age for females was 40.6 (SD = 13.70), the mean age for males was 44.9 (SD = 14.62), whereas the general mean age value was 42.75 (SD = 14.34). Concerning the bicycle use, 365 (15.3%) participants used a bicycle 1-3 times a month, other 707 (29.7%) participants cycled 1-2 days a week, 872 (36.6%) did so three or more days a week, and the remaining 437 (18.4%) cycled daily.

**Measures**

The survey comprised the following sections: Cycling frequency, Trip purpose and Modal split between bicycle and car which were used as segmentation variables; Socio-demographic characteristics, Attitudes towards cycling, Infrastructure rating, discomfort while cycling in mixed traffic, Motorist behaviour rating and Comparative cycling risk perception were instead used as profiling variables.

*Cycling frequency* has been considered as the product of the number of days cycled per month and months cycled per year. It was measured using 2 items: "How many months a year do you normally cycle?" with answers from 1 to 12, and "In general, during these months, how often do you cycle?" with answers on a 5-point scale (1 = daily, 2 = 3 or more days per week, 3 = 1-2 days per week, 1 to 3 times a month, 5 = less than once a month).

*Cycling trip purpose*. Respondents were asked the reason why they use the bicycle with three dichotomous (Yes/No) items, which asked if they used the bicycle for: commuting/travelling to or from work/college, personal business (e.g., shopping/entertainment, health appointments, or visiting family/friends), and leisure/training. We distinguished non-commuting trips into two categories: leisure and sports trips (e.g. bike excursion and sightseeing bike ride, competitive cycling training, or bike race) and personal business trips (e.g. using the bike for shopping, visiting relatives or friends, health appointments). In the present study, we used cycling trip purposes to ascertain differences and similarities among European cyclists. This is particularly relevant since it can help to identify strategies to increase cycling levels between different segments of the population. We clustered our sample of cyclists according to the reasons why they cycle, explicitly aiming at identifying differences between commuting and non-commuting trips.

*Modal split* between bicycle and car was assessed using one question about the car and one question about the bicycle usage during months of cycling (i.e., "In general, during the months you cycle, how often do you travel in a car, whether as a driver or passenger?"). Both items were measured on a 6-point scale (1 = daily, 2 = 3 or more days per week, 3 = 1-2 days per week, 1 to 3 times a month, 5 = less than once a month, 6 = never). Answers were then combined into a new variable coded as 1 = more car than the bicycle, 2 = same, 3 = more bicycle than the car, and 4 = bicycle only. Clustering cyclists, according to modal split, brought insights on their habits and helped understand if the increase in cycling demand could grow (Streit et al., 2014). It becomes particularly relevant to the present study because it can allow discerning which group has higher potential to switch towards sustainable mobility. In the present study, we used modal split to investigate respondents' use of car or bicycle as primary means of transport.

*Socio-demographic characteristics*. The online survey asked participants to state their age, gender, country of residence, and job status. As for the latter, participants were asked to select one of the following options: full time employed, part-time employed, self-employed, not currently working, students, homemaker, full-time caregiver and retired. Eventually, participants were recategorised in three groups basing on their answers: those who are actively involved in a job (employed); those who are students; and those who have no contractual employment or have retired (unemployed). The present study aimed at assessing clusters of cyclists, in a sizeable cross-national sample, to explore differences and similarities in terms of socio-demographic characteristics of different typologies of cyclists in different countries, following the recommendation by Félix et al. (2017),.

*Attitudes towards cycling.* To appraise participants' hedonic attitudes towards cycling, we used three items that expressed positive feelings towards cycling (e.g., pleasant, mentally relaxing).

Instrumental attitudes were instead measured through four items asking about perceived functionality and convenience of the bicycle (e.g., time-saving, affordable). Finally, four items were used to evaluate the expected benefits of cycling (e.g., environmental and health benefits). We added flexibility as an additional aspect of health and environmental benefits. All items were rated on a 5-point scale (1 = completely disagree to 5 = completely agree). Exploratory factor analyses with principal axis factoring yielded a one-factor solution for all three attitudes towards cycling, with no differences across countries. Cronbach's alpha reliability coefficient was 0.85 for hedonic attitudes, 0.83 for instrumental attitudes, and 0.75 for benefits.

*Rating of the cycling infrastructure*. We asked the participants to evaluate on a 5-point scale (1 = very poor to 5 = excellent) the overall level of the cycling infrastructure with two items referring to the quality and provision of the infrastructure (e.g., "How would you rate the cycling infrastructure in terms of the level of provision of cycling infrastructure?"). Cronbach's alpha reliability coefficient was 0.92. In the present study, respondents' evaluation of cycling infrastructure in terms of quality and provision has been included to understand whether it would increase the chances of belonging to one cluster compared to the others.

*Discomfort while cycling in mixed traffic*. Participants were asked to assess their level of discomfort on the following six scenarios: (1) cycling in a path separated from the street; (2) in a two-lane (one in each direction) urban commercial shopping street, and no bike lane; (3) cycling in the previous scenario with a striped bicycle lane added; (4) in a major urban or suburban street with four lanes (2 in each direction) and no bike lane; (5) cycling in the previous scenario with a striped bike lane added or (6) with a bike lane separated from traffic by parked card or a curb. All items were rated on a 5-point scale (1 = very comfortable to 5 = very uncomfortable). Exploratory factor analyses with principal axis factoring and quartimax rotation yielded a two-factor solution. In the present study, only the first factor has been considered since it comprises cycling in mixed traffic without a bike lane (scenario number 2 and 4 with a factor loading of .91 and .74 respectively). Cronbach's alpha reliability coefficient was 0.81. Given the importance of cyclists' feeling of comfort in mixed traffic, we considered it when profiling the obtained clusters.

*Motorist behaviour rating*. To investigate in how cyclists see and assess the conduct of drivers, the participants replied to the following question using a 5-point scale (1 = very poor to 5 = excellent): "How would you rate the driving behaviour of motorists and van/truck drivers within the environment you mainly cycle in?".

*Comparative cycling risk perception*. We assessed the comparative cycling risk perception by asking participants to estimate their likelihood of being involved in an accident compared with that of their peers (i.e. "Compared to other bicycle riders of my age and sex, my risk of being involved in a traffic accident is?), as similarly done in previous studies (Friedman, 2011; Martha & Delhomme, 2009; Schwarzer, 1999). The item was rated on a 5-point scale (1 = much smaller to 5= much higher).

**Statistical analysis**

To assess differences in respondents' characteristics between countries in terms of age, cycling levels, attitudes towards cycling, discomfort while cycling in mixed traffic and comparative cycling risk perception we used analysis of variance (ANOVA) with Welch's correction and Games-Howell pairwise comparisons. We used $\chi^2$ tests with posthoc z-scores and Bonferroni correction to assess gender and employment status differences.

To identify segments of cyclists based on cycling patterns a two-step cluster analysis was performed using both categorical (i.e., cycling trip purpose, and relative use of the car vs bicycle) and continuous (i.e., riding frequency) segmentation variables. There are two main reasons behind the choice of clustering cyclists according to cycling patterns: first of all because, as we mentioned in the literature review, it has been proven to be a meaningful way to cluster cyclists and, to our knowledge, there are no attempts with a sample from six different countries. Also, utilizing numerous factors in the clustering phase would have prompted excessively convoluted segments, thus making discussing outcomes in a meaningful way particularly challenging. Hence, we used cycling habits (i.e., Cycling frequency, Trip purpose and Modal split) to profile the segments, as those variables reflected the actual usage of the bicycle by participants. Segments would later be profiled in terms of cyclists' personal and psychosocial related characteristics. To determine the optimal number of clusters, we used the log-likelihood as the distance measure between clusters and Schwarz's Bayesian information criterion. The silhouette coefficient, which compares the average within-cluster cohesion with the average between-cluster separation, was examined to assess the goodness-of-fit of the cluster solution. Values between 0.20 and 0.50 indicate a proper fit, and values of 0.50 or more a good fit (Sarstedt & Mooi, 2014). For validation and interpretation of the cluster solution, $\chi^2$ tests and ANOVAs were performed on categorical and continuous segmentation variables, respectively.

We performed a multinomial logistic regression analysis to profile the segments. Segment membership was set as the outcome variable (coded as 1 = member and 0 = not member). Socio-demographics, attitudes towards cycling, discomfort in mixed traffic, cycling infrastructure and motorist behaviour ratings, and cycling risk perception were entered as independent variables. The model $\chi^2$, Pearson and deviance tests, and Nagelkerke Pseudo-$R^2$ were considered to assess the

goodness-of-fit of the logistic regression model. A significant $\chi^2$ indicates that the model, with its independent variables, fits the data better than a model without those variables. Nonsignificant Pearson and deviance tests indicate nonsignificant differences between the observed and the predicted probabilities. Nagelkerke R2 values larger than 0.20 represent an acceptable approximate amount of explained variability (Hosmer & Lemeshow, 2000). Odds ratios and 95% confidence intervals (C.I.s) were reported for each independent variable.

Interpretation of results was based on both statistical significance ($p < 0.05$) and measures of effect size: Cramer's V of 0.10 was considered small, 0.30 medium, and 0.50 large; $\eta 2$ of 0.01 was considered small, 0.06 medium and 0.14 large; Cohen's d of 0.20 was considered small, 0.50 medium, and 0.80 large; and O.R.s of 1.5 were considered small, 3.5 medium, and 9 large (Cohen, 1988). Data were analysed using IBM SPSS 23.

### 2.1.2. Results

#### Respondents' characteristics

The total sample (N = 2,381) was 50.6% female and mean aged 43 years (SD = 14.34), with 67.8% being employed. The cyclists' characteristics in the total sample and by country are displayed in Table 2. Cyclists from Hungary were slightly younger than those from The Netherlands (d = 0.23) and Spain (d = 0.22). Chi-square tests followed by pairwise comparisons indicated that: there were more cyclists who were students in Sweden compared to United Kingdom, Italy, and Spain; more cyclists who were employed in United Kingdom, Italy, and Spain than in The Netherlands and Sweden; more cyclists who were unemployed/retired in The Netherlands than in Hungary, Italy, and Spain. Table 2 illustrates an overview of the sample characteristics across countries.

Table 2

*Respondents' characteristics across the six countries.*

| | Total ($N$ = 2,381) | United Kingdom ($n$ = 396) | The Netherlands ($n$ = 395) | Sweden ($n$ = 392) | Hungary ($n$ = 399) | Italy ($n$ = 403) | Spain ($n$ = 396) | Country differences |
|---|---|---|---|---|---|---|---|---|
| Female gender, *n* (%) | 1,210 (50.8) | 202 (51.0) | 199 (50.4) | 219 (55.9) | 200 (50.1) | 187 (46.4) | 203 (51.3) | $\chi^2_5 = 7.29$; $V = .06$ |
| Age, *M* ± *SD* | 42.75 ± 14.34 | 42.59 ± 15.04 | 44.00 ± 15.60 | 43.31 ± 16.17 | 40.58 ± 14.42 | 42.67 ± 12.34 | 43.34 ± 11.80 | $F_{5,1104.885} = 2.61^{*}$; $\eta^2 = .01$ |
| (range) | (18-86) | (18-86) | (18-85) | (18-86) | (18-74) | (19-82) | (19-81) | |
| Employment status, *n* (%) | | | | | | | | $\chi^2_{10} = 43.99^{**}$; $V = .10$ |
| Student | 196 (8.2) | 25 (6.3)[a] | 38 (9.6)[a, b] | 50 (12.8)[b] | 34 (8.5)[a, b] | 26 (6.5)[a] | 23 (5.8)[a] | |
| Employed | 1,617 (67.9) | 282 (71.2)[a] | 232 (58.7)[b] | 240 (61.2)[b, c] | 277 (69.4)[a, c] | 294 (73.0)[a] | 292 (73.7)[a] | |
| Unemployed/retired | 568 (23.9) | 89 (22.5)[a, b] | 125 (31.6)[b] | 102 (26.0)[a, b] | 88 (22.1)[a] | 83 (20.6)[a] | 81 (20.5)[a] | |

*Note*. Proportions with different superscript letters in the same row are significantly different from each other at $p < 0.05$.

$^{*}$ $p < 0.05$.

$^{**}$ $p \leq 0.001$.

### Segments of cyclists based on cycling patterns

The two-step cluster analysis yielded a three-segment solution (Table 3). The average Silhouette coefficient was 0.40, indicating fair-to-good cohesion and separation. The ratio between the most extensive and smallest cluster was 1.15, indicating balanced cluster sizes.

The first segment (n = 727) constituted 30.5% of cyclists and was characterised by using the bicycle solely for leisure/training activities, a clear preference for car relative to bicycle, and low riding frequency. This segment was named Leisure-time Cyclists. The second segment (n = 839), which amounted to 35.2% of the total sample, was characterised by a high variety of cycling trip purpose, a clear preference for bicycle relative to the car, and high riding frequency. This segment was called Resolute Cyclists. The third segment (n = 815), which corresponded to 34.2% of respondents, was characterised by cycling for personal business or leisure/training but not for commuting, no distinct preference between bicycle or car, and medial riding frequency. This segment was identified as Convenience Cyclists. All comparisons between segments on the segmentation variables were significant at $p < .001$, with medium to large effect sizes (Table 3).

To provide more details about the distinctive characteristics of each segments, we considered additional variables when comparing each group (Table 4). Specifically, we investigated whether there were meaningful differences between the groups in terms of discomfort while cycling in mixed traffic, cyclists' ratings on the quality and provision of infrastructure, cyclists' assessment of motorised vehicles drivers' behaviour and cycling comparative risk perception. One-way ANOVA revealed that participants belonging to the Resolute Cyclists cluster reported significantly lower feeling of discomfort while pedalling in streets without a dedicated bike path ($F2, 1582.36 = 8.34$; $\eta 2 = .01$) than the group of Leisure-time Cyclists and Convenience Cyclists. Moreover, cyclists belonging to the Resolute cluster rated both the quality and the provision of the cycling infrastructure ($F2, 2378 = 43.50$; $\eta 2 = .03$) and motorists' behaviour ($F2, 2378 = 8.32$; $\eta 2 = .01$), significantly higher than that of the other groups. Finally, significantly lower cycling risk perception ratings where reported by Resolute Cyclists and Convenience Cyclists compared to ratings reported by Leisure-time Cyclists ($F2, 1578,11 = 6.02$; $\eta 2 = .01$).

Table 3

*Segments of cyclists on the segmentation variables.*

| | Leisure-time Cyclists ($n$ = 727) | Resolute Cyclists ($n$ = 839) | Convenience Cyclists ($n$ = 815) | Segment differences |
|---|---|---|---|---|
| Trip purpose[†] | | | | |
| Commuting | 0%[a] | 89.5%[b] | 0%[a] | $\chi^2_2 = 2016.20^*$; $V = .92$ |
| Personal business | 0%[a] | 64.6%[b] | 100%[c] | $\chi^2_2 = 1598.23^*$; $V = .82$ |
| Leisure/Training | 100%[a] | 50.5%[b] | 61.8%[c] | $\chi^2_2 = 484.01^*$; $V = .45$ |
| Modal Split | | | | |
| More car than bicycle | 63.8%[a] | 14.8%[b] | 41.5%[c] | $\chi^2_6 = 490.36^*$; $V = .32$ |
| Same | 17.3%[a] | 26.0%[b] | 27.7%[b] | |
| More bicycle than car | 16.1%[a] | 50.1%[b] | 30.8%[c] | |
| Bicycle only | 2.8%[a] | 9.2%[b] | 0%[c] | |
| Cycling frequency[‡] | 55.69[a] | 173.44[b] | 106.73[c] | $F_{2, 1544.35} = 313.33^*$; $\eta^2 = .19$ |

*Note*. Values with different superscript letters in the same row are significantly different from each other at $p < 0.05$.

[†] Proportions of cyclists who responded "Yes".

[‡] Riding frequency were computed as the number of months per year in which the person usually cycles and the number of days spent cycling each month. Range 2-365 ($M$ = 114.65, $SD$ = 110.10).

$^* p \leq 0.001$.

Table 4

*Socio-demographic, attitudinal and psychosocial characteristics of the three segments.*

| | Leisure-time Cyclists ($n$ = 727) | Resolute Cyclists ($n$ = 839) | Convenience Cyclists ($n$ = 815) | Segment differences |
|---|---|---|---|---|
| *Socio-demographics* | | | | |
| Country, *n* (%) | | | | $\chi^2_{10} = 310.18^*$; $V = .26$ |
| UK | 153 (21.0) | 137 (16.3) | 106 (13.0) | |
| The Netherlands | 24 (3.3) | 180 (21.5) | 191 (23.4) | |
| Sweden | 97 (13.3) | 179 (21.3) | 116 (14.2) | |
| Hungary | 82 (11.3) | 155 (18.5) | 162 (19.9) | |
| Italy | 145 (19.9) | 109 (13.0) | 149 (18.3) | |
| Spain | 226 (31.1) | 79 (9.4) | 91 (11.2) | |
| Gender, *n* (%) | | | | $\chi^2_2 = 2.31$; $V = .03$ |
| Female | 366 (50.3) | 413 (49.2) | 431 (52.9) | |
| Male | 361 (49.7) | 426 (50.8) | 384 (47.1) | |
| Age, $M \pm SD$ (range) | 45.01 ± 13.82 (18-86) | 38.22 ± 12.63 (18-81) | 45.38 ± 15.28 (18-85) | $F_{2, 1557.39} = 74.28^*$; $\eta^2 = .05$ |
| Employment status, *n* (%) | | | | $\chi^2_4 = 165.16^*$; $V = .19$ |
| Students | 43 (5.9) | 109 (13.0) | 44 (5.4) | |
| Employed | 488 (67.1) | 644 (76.8) | 485 (59.5) | |

| | | | | |
|---|---|---|---|---|
| Unemployed | 196 (27.0) | 86 (10.3) | 286 (35.1) | |
| *Attitudinal* | | | | |
| Hedonic | 4.15[a] | 3.99[b] | 4.13[a] | $F_{2,\ 1574.37} = 8.80$; $\eta^2 = .01$ |
| Instrumental | 3.08[a] | 3.24[b] | 3.23[b] | $F_{2,\ 1559.33} = 7.57$; $\eta^2 = .01$ |
| Benefits | 3.96[a] | 4.13[b] | 4.07[b] | $F_{2,\ 2378} = 11.18$; $\eta^2 = .01$ |
| Discomfort in Mixed Traffic | 3.48[a] | 3.27[b] | 3.43[a] | $F_{2,\ 1582.36} = 8.34$; $\eta^2 = .01$ |
| Infrastructure Rating | 2.88[a] | 3.36[b] | 3.20[c] | $F_{2,\ 2378} = 43.50$; $\eta^2 = .03$ |
| Motorist behaviour | 2.76[a] | 2.95[b] | 2.83[a] | $F_{2,\ 2378} = 8.32$; $\eta^2 = .01$ |
| Cycling Risk perception | 2.87[a] | 2.75[b] | 2.76[b] | $F_{2,\ 1578,11} = 6.02$; $\eta^2 = .01$ |

*Note*. Values with different superscript letters in the same row are significantly different from each other at $p < 0.05$.

[*] $p \leq 0.001$.

**Profiling the segments**

We used the Leisure-time Cyclists' segment as the reference category in the multinomial logistic regression analysis. Table 5 displays the results. The model explained 32% of the variability (Nagelkerke Pseudo-R2 = 0.32), with no evidence of poor fit (model $\chi^2 32 = 797.89$, $p < .001$; Pearson $\chi^2 4726 = 4755.85$, $p = .38$, deviance $\chi^2 4726 = 4424.89$, $p = .99$). Regarding the likelihood of belonging to the Resolute Cyclist segment, it was lower among the UK, Spanish and Italian cyclists, compared to Swedish cyclists, with small effect sizes. In contrast, Dutch cyclists showed a higher odds of belonging to this segment with average effect sizes. Specifically, cyclists from Sweden were twice as likely as those from the United Kingdom (1/0.40) and three times (1/0.30) as likely as those from Italy to be in this segment. The analysis did not show any significant effect of Gender on belonging to the Resolute cyclist. At the same time, it was possible to highlight a significant effect of age and employment status. Particularly, young participants seemed more likely to be part of the Resolute Cyclists' category. The likelihood of belonging to the Resolute Cyclists segment decreased by 3% per each additional year of age. Furthermore, students and employed participants were relatively more likely than unemployed ones to be members of this segment. Regarding attitudes towards cycling, an increased likelihood of belonging to the Resolute segment was found for cyclists reporting lower hedonic attitudes and higher instrumental, and benefit-oriented attitudes. Specifically, a one-unit increase in hedonic attitudes was related to a 60% decrease in the odds of belonging to this segment. In contrast, a one-unit increase in instrumental and environment-oriented attitudes was linked, respectively, to a 49% and a 220% decrease in the odds of being a Resolute Cyclist. Lastly, cyclists reporting lower levels of discomfort while cycling in mixed traffic and higher cycling infrastructure rating were more likely to be members of this particular group. A one-unit increase in discomfort in mixed traffic was related to a 16% decrease in the odds of belonging to this segment. In comparison, a one-unit increase in cycling infrastructure rating was linked to a 21% increase in the odds of being a Resolute Cyclist. Cycling risk perception and cyclists' evaluation of motorists' behaviour were not found to have a significant relationship with the likelihood fo belonging to the Resolute Cyclists segment.

Focussing on Convenient Cyclists, the likelihood of belonging to this segment was higher among participants from The Netherlands and Hungary and lower among participants from the U.K. and Spain, compared to participants from Sweden. Cyclists from Hungary were twice as likely as those from Sweden to be in this segment whereas Dutch cyclists were seven times more likely to be part of this group. Differently, Swedish participants were twice as likely as those from the U.K. (1/0.54) to be Convenience Cyclists and four times as likely as those from Spain (1/0.24). It was not

possible to find a significant relationship between gender, age, and employment status and the odds of belonging to the Convenience Cyclists' segment. In this case, lower hedonic and higher benefit-oriented attitudes were significantly associated with being a Convenience Cyclist, with a one-unit increase in hedonic and environment-oriented attitudes being related, respectively, to a 36% decrease and an 84% increase in the odds of belonging to this segment. Finally, cyclists reporting a lower feeling of discomfort while cycling in mixed traffic and higher ratings of cycling infrastructure were more likely to be members of this group. Specifically, a one-unit increase in discomfort in mixed traffic was related to an 11% decrease in the odds of belonging to this segment. On the other hand, a one-unit increase in cycling infrastructure rating was linked to a 16% increase in the odds of being a Resolute Cyclist. Cycling risk perception and cyclists' evaluation of motorists' behaviour were not found to have a significant relationship with the likelihood fo belonging to the Resolute Cyclists segment.

Table 5.

*Multinomial Logistic Regression of segments on socio-demographic and attitudinal variables.*

| | *Resolute Cyclists* | | *Convenience Cyclists* | |
|---|---|---|---|---|
| Independent variable | B (SE) | OR (95% CI) | B (SE) | OR (95% CI) |
| *Socio-demographics* | | | | |
| Country (Sweden)[a] | | | | |
| UK | -0.91 (0.19)** | 0.40 (0.27-0.59) | -0.61 (0.20)* | 0.54 (0.78-1.02) |
| The Netherlands | 1.60 (0.27)** | 4.94 (2.91-8.39) | 1.95 (0.26)** | 7.05 (4.19-11.86) |
| Spain | -2.22 (0.21) ** | 0.11 (0.07-0.16) | -1.43 (0.20)** | 0.24 (0.16-0.36) |
| Hungary | 0.28 (0.21) | 1.33 (0.88-1.99) | 0.49 (0.21)** | 1.99 (1.33-2.97) |
| Italy | -1.19 (0.20)** | 0.30 (0.20-0.45) | -0.29 (0.20) | 0.75 (0.51-1.10) |
| Gender (Female)[a] | | | | |
| Male | 0.13 (0.12) | 1.14 (0.90-1.44) | -0.10 (0.12) | 0.90 (0.72-1.13) |
| Age | -0.03 (0.01)** | 0.97 (0.96-0.98) | -0.01 (0.01) | 0.99 (0.98-1.00) |
| Job status (Unemployed)[a] | | | | |
| Employed | 1.02 (0.17)** | 2.78 (2.00-3.87) | -0.29 (0.14) | 0.75 (0.57-0.98) |
| Students | 1.01 (0.28)** | 2.76 (1.58-4.80) | 1.32 (0.15) | 0.64 (0.37-1.12) |
| *Attitudinal* | | | | |
| Hedonic | -0.92 (0.11)** | 0.40 (0.32-0.48) | -0.44 (0.10)** | 0.64 (0.53-0.78) |

| | | | | |
|---|---|---|---|---|
| Instrumental | 0.40 (0.09)** | 1.49 (1.26-1.77) | 0.35 (0.08) | 1.41 (1.20-1.67) |
| Benefits | 1.16 (0.12)** | 3.20 (2.52-4.09) | 0.61 (0.12)** | 1.84 (1.46-2.32) |
| Discomfort in Mixed Traffic | -0.18 (0.06)* | 0.84 (0.74–0.95) | -0.12 (0.06)* | 0.89 (0.79-1.00) |
| Infrastructure Rating | 0.19 (0.07)* | 1.21 (1.06-1.38) | 0.15 (0.06)* | 1.16 (1.03-1.31) |
| Motorist behaviour | -0.12 (0.07) | 0.88 (0.77-1.01) | -0.11 (0.07) | 0.89 (0.78-1.02) |
| Cycling Risk perception | -0.03 (0.08) | 0.97 (0.83-1.13) | -0.13 (0.08) | 0.88 (0.76-1.02) |

*Note*. SE = standard error; CI = confidence intervals.

[a] Reference category.

* $p < 0.05$.

** $p \leq 0.001$.

### 2.1.3. Discussion

This research has made a substantial contribution in describing common patterns, attitudes and psychosocial characteristics of diverse segments of cyclists in Europe, which according to the literature, is one of the less investigated aspects if compared to other modes of transport (Handy et al., 2014). It was possible to classify three segments that substantially differ according to cycling trip purpose, modal split and cycling frequency.

Cyclists belonging to the first cluster have been named Leisure-Time cyclists. Those are cyclists using the bicycle almost exclusively for sport or recreational activity, with reduced cycling levels and a clear preference for using the car as their primary mean of transportation. Living in Sweden decreased the probability of belonging to this segment, especially if compared to the U.K., Spain and Italy. Results suggest that cyclists belonging to this cluster tend to perceive cycling as a pleasant and relaxing activity. However, they do not perceive it as a convenient mode of transport nor are interested in the benefits that everyday cycling could bring for themselves and society. Age and income appear to influence the likelihood of belonging to this cluster. In particular, older adults and unemployed people are more likely to be Leisure-time Cyclists.

Participants belonging to the second cluster were named Resolute Cyclists. Those are cyclists that preferred using the bicycle instead of the private car and cycle often for their everyday trips, especially for commuting. The odds of belonging to this cluster were increased by being in The Netherlands and Sweden, as well as being younger, student or being employed. Participants in this cluster attributed importance to the several benefits of cycling. However, they tended not to perceive cycling as a pleasant and relaxing activity. Resolute Cyclists attributed much importance to the benefits of cycling as a healthy and flexible means of transport. The probability of belonging to the

resolute cyclists' segment decreased as participants' age increased. This result may be connected to health-related issues or reduced mobility of elderly participants. It is also partially in line with results from Dill and Voros (2007) which showed that younger adults were more likely to be regular cyclists and that the significant drop-off in regular cycling occurred at age 55 years and above. Also, other researchers have shown that younger generations are more willing to use other modes of transport than the car (Delbosc & Currie 2013; Kuhnimhof et al. 2012). In a study by Prillwitz and Bar (2011) younger generations as been defined as "green travellers", suggesting a preference for active and sustainable means of transport. This preference could be dictated by many factors such as income constraints or delays in adult life transition (Delbosc & Currie, 2014), shifts in attitudes (Vij et al, 2017), differences in their daily activities or changes in the local transport or land-use systems (Delbosc et al., 2019). Furthermore, our results showed that respondents with higher instrumental and benefit-oriented attitudes were more likely to be members of this segment. This confirms results from Dill and Voros (2007), which showed that participants with positive attitudes towards cycling were more likely to be regular cyclists. The likelihood of being a Resolute Cyclists also decreased in participants reporting higher rating of discomfort while cycling in mixed traffic. Such a result confirms that not feeling comfortable sharing the road with motorised vehicles can influence cycling patterns and bicycle usage, in particular, prompting avoidance behaviours. Participants reporting positive ratings about the quality and provision of cycling infrastructure had a higher likelihood of belonging to this cluster. While it would be hasty to infer a direct causal relationship, in this case, it is still important to acknowledge that cycling patterns and bicycle use are closely related to cycling infrastructure provision and quality.

Participants belonging to the third identified cluster were named Convenience Cyclists. Those are cyclists that tend to use the bicycle almost exclusively for personal business or recreational activities, have moderate riding frequency and equally choose to ride a bicycle or to drive a car for their daily trips. Our results suggest that participants in this cluster are more likely to live in a country where cycling is a standard mode of transport (i.e. The Netherlands, Hungary). Participants in this cluster attributed importance to the many benefits of cycling, especially to environmental-related benefits. However, they tend not to consider cycling as a pleasant and relaxing activity. In line with findings by Dill and Voros (2007), we found a significant relationship between environmental values and utilitarian cycling. Respondents who thought air quality was a problem tried to limit their driving, and those who believed that their region did not need to build more highways were more likely to be utilitarian cyclists. Similarly to Resolute Cyclists, Convenience Cyclists had higher odds to report lower discomfort while cycling in mixed traffic and express positive values on the quality and

provision of cycling infrastructure in the areas where they ride most if compared to Leisure-time Cyclists.

According to our findings, it is worth discussing the relationship between participants' country of residence and its related societal and infrastructural feature. One of the main criteria for inclusion of specific countries in the present study was to have diverse average cycling modal shares, possibly reflecting different countries cycling culture. The selected countries hold, in fact, meaningful differences in terms of cycling levels (European Commission, 2014). Our results suggest that participants from countries where cycling is widespread (i.e. The Netherlands, Sweden and Hungary) have a lower chance of cycling for leisure than in countries where the percentage of people who reported daily cycling is low (i.e. Italy, Spain and the United Kingdom). Unsurprisingly, participants from high cycling countries also have higher chances of belonging to the category of Resolute Cyclists. National cycling culture, policies, sustainable mobility programs and initiatives about cycling safety are most likely to play an important role. It is possible to find research exploring the relationship between national policies and investments with cycling safety and popularity (Hull & O'Holleran, 2014; Kosztin et al., 2017) as well as the level of infrastructure provided to make cycling attractive (Pucher & Buehler, 2008). For instance, The Netherlands has been at the leading edge of initiatives to make cycling safe and preeminent and, as such, can be considered an exemplary "strong cycling culture" (Hull & O'Holleran, 2014). Sweden and Hungary have made considerable efforts in recent years to increase the share of cycling as well (Bastian & Börjesson, 2017; Koglin, 2017; Haustein & Nielsen, 2016) which translated in a tangible increase of people adopting the bicycle as the primary mean of transport (Pucher & Buehler, 2008). In accordance, our results suggest that when citizens are provided with adequate quality and provision of cycling infrastructure, there is a higher probability of them choosing to cycle more. The higher the perceived quality and provision of cycling infrastructure, the more likely a participant is to belong to the group of Resolute Cyclists and Convenience Cyclists. Both groups show a higher cycling frequency compared to Leisure-time Cyclists. Future studies should focus on investigating exactly how and through which psychosocial mechanisms such investment leads to more people using the bicycle as their main means of transport, especially when comparing countries with diverse levels of cycling.

Cycling frequency could also involve considerations about participant' level of physical activity. Active transportation helps to reduce the negative personal health effects connected to prolonged inactivity and sedentarism. In particular, cycling can help people to reach the WHO's physical activity recommendation, with many beneficial effects for their health (Raser et al., 2018). Even though acquiring detailed data on participants' time spent cycling, cycling intensity and

travelled distance was out of the scope of the current research, an assessment of the days spent cycling per year can provide approximate information on participants' levels of physical activity. Resolute Cyclists are the most active with, on average, 173 days spent cycling per year and a preference for using the bicycle instead of the car. Clear, well-documented and robust evidence supports that reducing car usage whilst increasing active transportation provides benefits to people's health (e. g. de Geus et al., 2008; Basset et al., 2008; Celis-Morales et al., 2017; ). Our study suggests that efforts should be focused on Leisure-Time Cyclists, who prefer using the car instead of bicycle and cycle only 56 days per year on average. Convenience Cyclists have possibly higher chances of switching towards daily active mobility since they have no clear preference between the use of the car or the bicycle and cycle around 107 days per year.

The present study also suggests that each type of cyclists could be differently responsive to campaign leveraging on specific messages. For instance, efforts should target Leisure-Time Cyclists and could leverage on the hedonic attitudes held by such a group. We suggest that messages stressing the pleasure of cycling, not only as a leisure activity but as an everyday transport means, could prompt Leisure-time cyclists to use the bicycle for purposes other than recreation or sport, possibly increasing their cycling levels. Since this category of cyclists already reports high ratings on hedonic attitudes, such type of message could foster a halo effect (Nisbett & Wilson, 1977) hopefully prompting a change in their bicycle patterns. Leisure-Time Cyclists could also be influenced by messages stressing the contextual opportunities and the positive consequences of the cycling mode. It is though worth mentioning that previous studies showed information about the adverse environmental effects of the car to be useful in raising public awareness but usually insufficient to prompt changes in behaviour (Tertoolen et al., 1998). Thus, care must be taken when choosing environmental concerns as core messages in campaign and interventions. In addition, it is essential to assume the existence of a bidirectional effect between cycling behaviour and its determinants, such as attitudes, preferences, and habits (Handy et al., 2014). Few decades ago, travel behaviour studies established that bidirectional effects exist between attitudes and behaviour (Dobson et al., 1978; Golob et al., 1979; Tardiff, 1977).

Results of the present study can also contribute to future versions of the European Cycling Strategy (ECF, 2017), providing insights specifically regarding policies and actions aimed at promoting behavioural change. Market segmentation has proven to be beneficial for tailoring communication and intervention for a specific purpose which is in this case, making cycling safer and more attractive for European Citizens. It is also beneficial for deciding which specific objectives should be pursued and which actions should be funded to maximise the expected impact of

interventions and making expenses more efficient. Clustering should be considered the preferred approach when investigating factors that could help to tailor policy and interventions to the different motivations and constraints of a broad target (Anable, 2005). We also suggest that such actions may be less about 'harder' infrastructural changes and more about 'softer' interventions with an emphasis on management and marketing activities. As it has been argued by Handy et al. (2014) policymakers can benefit from guidance on which of the possible strategies are likely to increase cycling and to what degree. Further studies focusing on that matter can help to empirically identify critical factors associated with cyclist preferences, attitudes and behaviours, pointing to a potentially effective strategy.

The most obvious shortcoming of the study described here are: firstly, the cross-sectional design does not allow to make strong causal inferences about present results. Secondly, social desirability and recall bias may have affected participant responses. Thirdly, the study population is self-selective (i.e. online panel) and, therefore, the generalizability of the findings is limited. Lastly, central tendency bias might have occurred due to the usage of five-point Likert type scales (Douven, 2018). The central tendency bias implies that participants tend to avoid the endpoints of a response scale and to prefer responses closer to the midpoint (Stevens, 1971),

## 2.2. STUDY 2: Gender differences in bicycle use, attitudes towards cycling and cycling injuries

Recent studies suggest that the health benefits of cycling are not equally distributed across different segments of the population. One possible reason is that the choice of using the bicycle is strongly linked to socio-economic factors (Heinen et al., 2010), including gender differences. Although gender differences in cycling appear to be context-specific (e.g. cycling culture), various studies showed that, in general, men report higher cycling levels than women (e.g. Garrard et al., 2012; Heesch et al., 2012; Moudon et al., 2005; Pucher et al., 2011; Pucher et al., 1999; Ryley, 2006, Twaddle et al., 2010; Wittmann et al., 2015). Past research attempted to investigate the possible cause of such a difference between men and women bicycle use. First, men tend to report fewer barriers or constraints to cycle and more positive attitudes to cycling compared to women (e.g. Akar et al., 2013; Dickinson et al., 2003; Emond et al., 2009; Garrard et al., 2012). Second, compared to men, women frequently report different attitudes towards cycling infrastructure and environments (e.g. a preference for slower traffic streets and segregation from motor traffic) and higher risk perception of cycling (Aldred et al., 2016; Beecham & Wood; 2014, Frings et al., 2012; Garrard et al., 2012; Griffin & Haworth, 2015; Heesch et al., 2012; Krizek et al., 2005). Third, gender differences could be

possibly related to culturally specific factors such as the cycling culture (Aldred et al., 2016) and gender inequality (Prati, 2018).

Moreover, it is difficult to establish a clear relationship between attitudes and behaviour. Bicycle use may, in fact, influence gender differences in attitudes towards cycling. This suggestion is backed up by the self-perception theory (Bem, 1967), which provides theoretical support for the hypothesis that cycling behaviour may influence attitudes towards cycling. The work of Bem (1967) showed that people tend to develop their attitudes by inferring them from observations of their behaviour. In this particular case, men may report more positive attitudes towards cycling because they cycle more than women. The self-perception theory may imply that one's attitudes towards cycling are influenced by the need to justify one's mobility behaviour. To our knowledge, no studies have investigated this hypothesis concerning bicycle use. However, indirect preliminary evidence can be found in a previous study involving members of a community cycling organization (Heesch et al., 2012). The authors found that women belonging to a community cycling organization were more likely to report positive attitudes towards cycling than men who did not belong to any cycling organization. However, ample evidence highlighted that identification might affect our attitudes (e.g. Bonaiuto et al., 1996; Martin & Epitropaki, 2001; Prati, Albanesi & Pietrantoni, 2017; Van Dick et al., 2007; Van Knippenberg & Van Schie, 2000). It is thus not clear whether this difference in positive attitudes was more related to one's self cycling behaviour or due to identification with the organization.

The primary objective of Study 2 was to examine gender differences in positive attitudes towards cycling in a population of regular cyclists (i.e., cyclists who cycle at least once a month) irrespective of their membership to an organization. Unlike previous evidence (e.g., Akar et al., 2013; Dickinson et al., 2003; Emond et al., 2009; Garrard et al., 2012), we would expect gender differences in positive attitudes towards cycling to flatten (Hypothesis 1). Furthermore, according to the same reasoning, the differences in cycling risk perception (Aldred et al., 2016; Beecham & Wood, 2014; Frings et al., 2012; Garrard et al., 2012; Griffin and Haworth, 2015; Heesch et al., 2012; Krizek et al., 2005) and evaluation of cycling infrastructure and built environment (Beecham & Wood, 2014; Garrard et al., 2012; Krizek et al., 2005) between male and female cyclists, in a sample of regular cyclists, are expected to be small or non-existent (Hypothesis 2 and 3). Summarising, we would expect gender differences in positive attitudes towards cycling, cycling risk perception and evaluation of cycling infrastructure in a population of regular cyclists to be small or non-existent since those are more dependent on own's behaviour, than on gender and culture, as suggested by preliminary evidence.

Given the main objective of study 2, it appears useful to investigate also gender differences in bicycle use in a population of regular cyclists. According to the social constructionist theory of gender (Beall, 1993; West & Zimmerman, 1987), we should expect gender differences in cycling patterns based on socially constructed views of masculinity and femininity. Authors found gender inequality to influence women's bicycle use (Prati, 2017). In particular, the traditional gender-related division of labour (e.g., gaps in time spent on caring activities and housework) may explain why women tend to use the bicycle for specific activities. Previous studies highlighted that women are more likely to report using the bicycle for non-commuting trips, such as taking children to or from school and carrying shopping by bicycle (Garrard et al., 2012). Hence, considering the gender role and identity, we should expect differences in terms of the purposes of cycling between man and women, such as female cyclists being more likely to use the bicycle for travelling with children and going for shopping compared to their male counterparts (Hypothesis 4). Unlike previous Hypothesis (i.e., 1,2 and 3) cycling patterns would differ between male and females cyclists since preliminary evidence suggests those are related to social and cultural factors.

Additionally, competitive cycling has patriarchal characteristics in Western countries (e.g. Adams et al., 2010; Bryson, 1987; Connell, 1995; Dunning, 1986; Koivula, 1999; Wellard, 2002). Most of the famous cycling competitive events such as Tour de France or Giro d'Italia are reserved exclusively for males. Even though women's famous cycling road races exist (e.g. UCI Road World Championships Women's road race), identification with the masculine image of cycling may lead to gender differences in sport participation. Such an idea would significantly influence training and leisure cycling and possibly leads to an under-representation of women among sport and recreational cyclists. Accordingly, we expect that male, compared to female cyclists, are more likely to use the bicycle for recreation or training purposes (Hypothesis 5). Furthermore, as per the earlier work of de Geus et al. (2014), which involved a sample of regular cyclists, commuting cycling is more frequent among males than females. Other authors (e.g., Garrard et al., 2012) suggested that, due to the traditional sexual division of labour, women's travel behaviour is more likely to include trip chaining (i.e., pick up children from school, grocery shopping). These findings suggest that additional barriers to commuter cycling exist. We hypothesise that bicycle use for work trips are more frequent among male cyclists than female cyclists (Hypothesis 6).

Lastly, we aimed at preliminarily encompassing cycling safety differences between males and females. The third aim of Study 2 was thus to investigate gender differences in cycling injuries. Past research showed that male cyclists have a higher likelihood of suffering severe cycling injuries than female cyclists (Bíl et al., 2010; Eluru et al., 2008; Marín Puchades et al., 2017; Prati, Pietrantoni &

Fraboni, 2017). However, there is little evidence that the likelihood of suffering severe injuries is higher among men than women when considering a sample of regular cyclists. In line with past research, we could argue that gender difference in the likelihood of severe injuries is only partially related to bicycle use and it is mainly linked to differences in skills, risk perception, attitudes and risky behaviours (Cobey et al., 2013; Cordellieri et al., 2016; Johnson et al., 2011; Schantz, 2017; Useche, Montoro, Alonso et al., 2018). Hence, in our sample, which is composed of regular cyclists, we expect to find a higher exposure to severe accidents among male cyclists than among female cyclists (Hypothesis 7).

It is also essential to take into consideration the potential effect of the geographical context on gender differences. As a matter of facts, European countries differ in terms of topography, psychosocial factors, politics, economy, bicycle culture, and road infrastructures. To account for these differences, we included the role of countries in our analyses. The effect of the specific country was estimated in an exploratory way. Thus, we did not raise any particular hypothesis on that matter.

### 2.2.1. Materials and methods

#### Procedure

The procedure for Study 2 is the same as Study 1. Summing up, the following steps have been pursued: (1) pilot version of the questionnaire in English administered to 60 participants; (2) scrutinizing the pilot questionnaire data led to changes of questions which produced anomalous replies; (3) the finalised version of the questionnaire was translated, sense checked by native speakers, uploaded to a customised online survey platform, and administered to 2417 participants; (4) after response collection ended, data from participants who responded with the same values within a scale or who completed the questionnaire in a time shorter than a pre-established limit was eliminated, leaving a sample of 2389 participants included in the analysis.

#### Measures

As mentioned in Study 1, the questionnaire contained items on demographic information such as age, gender, student status, working status, having children under 12 years of age in household, and nationality. Other areas included information about cycling frequency, attitudes towards cycling, perceived safety when cycling, cycling infrastructure and the cycling environment. Few scales were computed in a slightly different way in order to fit the objectives of Study 2 better. Measures included in the present study are the following:

*Cycling frequency.* To measure cycling frequency, participants answered the question "How many months a year do you normally cycle?". Asking the participants how many months a year they use the bicycle would prompt them to think at specific months/seasons in most cases. This item allowed us to account for local geographical differences in terms of weather limitations for bicycle use as well. Participants were also asked: "In general, during these months, how often do you cycle?", with answers on a five-point scale ranging from 1 (daily) to 5 (less than once per month). We calculated the yearly trip values by multiplying the number of months by the number of trips per months.

*Attitudes towards cycling*. Participants' attitudes towards cycling were evaluated with 14 questions. We included questions such as "How far do you agree that you cycle because it is pleasant?", "How far do you agree that you cycle because it is physically relaxing?" or "How far do you agree that you cycle because of the environmental benefits?". For each item, responses ranged from 1 (completely disagree) to 5 (completely agree). We developed this measure based on a review of the literature, pilot testing of draft items, and refinement of the instrument. We did exploratory factor analysis to investigate the dimensions of positive attitudes towards cycling, using principal axis factoring followed by quartimin rotation. Parallel analysis indicated a two-factor solution. A total of 51.7% variance was explained by exploratory factor analysis. The variance explained by each factor of the rotated two-factor solutions was, respectively, 41.6% and 10.1%. Absolute factor loadings greater than 0.40 were considered salient. One item (i.e., "How far do you agree that you cycle because it offers privacy?") was dropped because of its low factor loading on both factors. The first factor was about the benefits of cycling for the person and his or her environment. We labelled this factor as "Personal benefits". We labelled the second-factor "Benefits of cycling as a mean of transport" because the questions refer to the positive aspects of using cycling as a mean of transport in everyday life. Cronbach's alpha for the two factors was .85 and .87. respectively.

*Comparative risk perception.* As we did in Study 1, a single 5-point scale item was administered to participants to assess their perception of risk when cycling, in comparison to other bicycle users. Previous research has shown that people tend to underestimate their own risk levels (Caponecchia, 2010). This phenomenon is known as optimism bias. To address the optimism bias, we asked participants to assess their risk levels in relation to the reference group of cyclists of the same age and sex with the question, "Compared to other bicycle riders of my age and sex, my risk of being involved in a traffic accident is…". Answers ranged from 1 (much smaller) to 5 (much higher).

*Rating of the cycling infrastructure.* We assessed participants' attitudes towards cycling infrastructure and environment using two 5-point scale items: "How would you rate the cycling

infrastructure in terms of the level of provision of cycling infrastructure?"; "How would you rate the cycling infrastructure in terms of the quality of the cycling infrastructure?". Responses for each question ranged from 1 (excellent) to 5 (very poor). Correlation between the two items was .87, so we computed both into a single variable.

*Perceived discomfort on different types of roads*. As in Study 1, we asked participants the following question "How comfortable would you be to cycle in the following scenarios?": (1) "A path separated from the street"; (2) "a two-lane (one in each direction) urban commercial shopping street with no bike lane"; (3) "a two-lane (one in each direction) urban commercial shopping street, with a striped bicycle lane; (4) "a major urban or suburban street with 4 lanes (2 in each direction) and no bike lane"; (5) "a major urban or suburban street with 4 lanes (2 each direction) and a striped bike lane"; (6) "a major urban or suburban street with 4 lanes (2 each direction) and a bike lane separated from traffic by parked cars or a curb". Response options ranged from 1 (very comfortable) to 5 (very uncomfortable). We conducted a factor analysis of the six items measuring the level of discomfort reported by participants. We employed principal axis factoring, followed by quartimin rotation. Parallel analysis indicated a two-factor solution. Exploratory factor analysis explained 53.9% of the variance (two factors of 36.0% and 17.9%). Considering salient absolute factor loadings greater than 0.40, the first factor included the two scenarios without a bike lane ("Discomfort without bike lane"). The second factor comprised the remaining four scenarios that involved a bike lane ("Discomfort with bike lane"). In Study 2 we considered both factors since we were interested in assessing perceived comfort not only in relation to cycling in mixed traffic but for cycling infrastructure in general. Reliability of the two factors was satisfactory: r = .69 (first factor) and $\alpha$ = .82 (second factor).

*Cycling trip purpose*. A multiple-choice question was administered to investigate eight possible reasons behind participants' use of the bicycle. "Why do you make these cycle journeys?": commute/travel to or from work, travel to or from college/university, taking children to or from school, for business trips, shopping/entertainment, personal business (e.g. health appointment), visiting family/friends, leisure/training (e.g. a ride in the countryside)." Participants were allowed to select more than one of the alternatives if they applied. For the current analyses, all positive responses for each purpose of cycling were recoded as 1, while non-responses were recoded as "0" and considered as if bicycle were not used for that purpose.

*Exposure to severe crashes.* We used two items as a measure of exposure to severe crashes: "In the past 2 years whilst cycling, have you had an accident so severe that you had to see a doctor or were taken to a hospital?" with the options 1 (No), 2 (Yes, I had to see my doctor but did not need to

go to the hospital), 3 (Yes, I had to visit a hospital as an outpatient), and 4 (Yes, I had to stay in hospital overnight), and "In the past 2 years whilst cycling, have you had an accident whereby your bike was damaged?" with options 1 (No), 2 (Once), 3 (Twice), and 4 (More often).

**Statistical Analysis**

We conducted the analyses using IBM SPSS 23. In our investigation, we also controlled for the effect of cycling frequency and socio-demographic variables (i.e. age, student status, working status, having children under 12 years of age in household and nationality). In Study 2, we used multivariate analysis of variance (MANOVA) to address the first objective, which is investigating the effect of gender on attitudes towards cycling, comparative risk perception, evaluation of cycling infrastructure and cycling environment, and perceived discomfort on different types of roads. MANOVA is designed to investigate the effect of independent variables on several continuous dependent variables simultaneously. To test the multivariate effects, we chose Pillai's criterion because of its advantage in terms of robustness (Tabachnick & Fidell, 2013). We employed Sidak correction as an adjustment for post hoc pairwise comparisons. Sidak correction is quite similar to the Bonferroni correction but has the benefit of being less conservative. To address the second objective, which was to investigate the influence of gender on purposes of cycling, we used multiple logistic regression analysis. Eventually, we used ordinal regression analysis to address the third objective of study 2, which was to examine the effect of gender on previous involvement in bicycle accidents.

### 2.2.2. Results

Sample characteristics are the same as Study 1. Answers from a total of 2381 participants were included in the final dataset. Of these, 1171 (49%) were male, 1210 (50.6%) were female. Mean age ranged from 18 to 86 years old. Mean age for women was 40.6 (SD = 13.70), while the mean age for male was 44.9 (SD = 14.62). The total sample means age was 42.75 (SD = 14.34). With regards to 'frequency of cycling', 365 (15.3%) participants cycled 1-3 times a month, 707 (29.7%) cycled 1-2 days a week, 872 (36.6%) 3 or more days a week, and the remaining 437 (18.4%) participants cycled daily.

To what regards the first objective of Study 2, Table 5 shows the results of multivariate and univariate analyses of variance for attitudes towards cycling, discomfort on a different type of roads, evaluation of the cycling infrastructure and risk perception. Analysis of data using Pillai's trace showed a significant effect of gender and country while the interaction between country and gender was not significant, $F(6, 2364) = 1.07$, $\eta 2 = .00$. Independent univariate ANOVAs for gender revealed

non-significant effects of Attitudes toward cycling (Hypothesis 1), Discomfort with a bike lane, and Rating of the cycling infrastructure (Hypothesis 3). In addition, independent univariate ANOVAs highlighted a significant effect of Attitudes towards cycling related to personal benefits (Hypothesis 1), Discomfort without bike lane (Hypothesis 3), and Comparative risk perception (Hypothesis 2). Post-hoc pairwise comparisons allowed to pinpoint that:

- to what regards Attitudes toward cycling, female cyclists were more likely to report Personal benefits compared to male cyclists, $p < .001$;
- in relation to Perceived discomfort on different types of roads, female cyclists reported higher discomfort on roads without a bike lane compared to male cyclists, $p < .001$;
- regarding Comparative risk perception, female cyclists reported higher scores in comparison to male cyclists, $p = .001$.

A closer look at scores on Mobility and Personal benefits revealed they were higher among Spanish and Italian participants, while were lower among Dutch participants. Hungarian participants reported the highest score on perceived discomfort on roads without bike lanes, while participants from the UK reported the lowest score. Whilst participants from Italy, Sweden, Spain, and the U.K. reported substantially similar scores regarding Perceived discomfort on roads with bike lanes, and the highest observed values were among Dutch and Hungarian participants. Italian participants reported that the lowest rating of the cycling infrastructure, while ratings of quality and quantity of cycling infrastructure were highest among Dutch participants. Finally, Hungarian participants reported the lowest scores on risk perception while participants from the other countries reported substantially similar scores.

Table 5.

*Multivariate and Univariate Analyses of Variance for Perceptions and Attitudes Towards Cycling*

| Variable | MANOVA $F(6, 2364)$, $\eta^2$ | ANOVA $F(1, 2359)$ | | | | | |
|---|---|---|---|---|---|---|---|
| | | Mobility benefits | Personal benefits | Discomfort without bike lane | Discomfort with bike lane | Rating of the cycling infrastructure[1] | Risk perception |
| Gender | 16.21***, $\eta^2$ = .04 | $F$ = 0.33 | $F$ = 26.35*** | $F$ = 60.61*** | $F$ = 2.51 | $F$ = 3.31 | $F$ = 10.26*** |
| Men *M* (SE) | | 3.14 (0.04) | 4.04[a] (0.03) | 3.27[a] (0.05) | 1.92[a] (0.03) | 2.75[a] (0.05) | 2.74[a] (0.04) |
| Women *M* (SE) | | 3.16 (0.04) | 4.18[b] (0.03) | 3.60[b] (0.05) | 1.88[a] (0.03) | 2.82[a] (0.05) | 2.84[b] (0.04) |
| Country | 33.42***, $\eta^2$ = .08 | $F$ = 37.67*** | $F$ = 49.87*** | $F$ = 23.22*** | $F$ = 54.49*** | $F$ = 69.79*** | $F$ = 11.92*** |
| UK *M* (SE) | | 3.17[a] (0.05) | 4.09[a] (0.04) | 3.04[a] (0.06) | 1.82[a] (0.04) | 2.66[a] (0.06) | 2.81[ab] (0.05) |
| Netherlands *M* (SE) | | 2.82[b] (0.05) | 3.78[b] (0.04) | 3.50[b] (0.07) | 2.21[b] (0.04) | 2.16[b] (0.06) | 2.87[a] (0.05) |
| Spain *M* (SE) | | 3.62[c] (0.05) | 4.35[c] (0.04) | 3.26[c] (0.06) | 1.71[ac] (0.04) | 2.96[c] (0.06) | 2.92[ac] (0.05) |
| Hungary *M* (SE) | | 3.00[d] (0.05) | 4.04[a] (0.04) | 3.74[d] (0.07) | 2.15[b] (0.04) | 3.07[c] (0.06) | 2.57[d] (0.05) |
| Italy *M* (SE) | | 3.30[a] (0.05) | 4.34[c] (0.04) | 3.53[b] (0.06) | 1.69[c] (0.04) | 3.31[d] (0.06) | 2.86[ac] (0.05) |
| Sweden *M* (SE) | | 3.01[ad] (0.05) | 4.08[a] (0.04) | 3.51[b] (0.06) | 1.80[ac] (0.04) | 2.54[a] (0.06) | 2.69[bd] (0.05) |

*Note*. Multivariate *F* ratios were generated from Pillai's statistic. ANOVA = univariate analysis of variance. MANOVA = multivariate analysis of variance. * $p < .05$. ** $p < .01$. *** $p < .001$. Means in a column sharing the same superscript are not significantly different from each other according to post-hoc tests. [1] Higher scores correspond to a worse rating of the cycling infrastructure. Analyses were controlled for the effect of age, cycling frequency, working status, student status, and having children in household on the outcome.

Table 6.

*Multiple Logistic Regression Analyses (Odds Ratio) Predicting Eight Purposes of Cycling from Gender among Six European Countries*

| Variable | Commute/travel to or from work | Travel to or from college/ university | Taking children | Business trips | Shopping-entertainment | Personal business | Visiting family/friends | Leisure-training |
|---|---|---|---|---|---|---|---|---|
| UK | 0.55* | 0.89 | 0.92 | 0.54 | 0.95 | 0.63 | 1.53 | 1.05 |
| Netherlands | 1.07 | 0.61 | 2.14* | 0.54 | 2.15* | 1.88* | 1.28 | 0.55* |
| Spain | 0.67 | 2.37 | 1.60 | 4.22 | 1.35 | 1.21 | 0.87 | 1.00 |
| Hungary | 1.12 | 1.80 | 1.73 | —[a] | 1.39 | 1.46 | 1.26 | 1.21 |
| Italy | 1.07 | 0.94 | 1.76 | 1.03 | 1.35 | 1.24 | 1.20 | 0.63 |
| Sweden | 0.86 | 1.11 | 0.60 | 1.64 | 0.80 | 0.86 | 0.99 | 1.35 |

*Note*. * $p < .05$. P-values are for odds ratio. Gender was coded as 1 (male) or 2 (female). [a] few participants reported using bicycle for that purpose and, therefore, it was not possible to calculate reliable estimates. Analyses were controlled for the effect of age, cycling frequency, working status, student status, and having children in household on the outcome.

The results of multiple logistic regression analyses, assessing the eight purposes of cycling from gender, cycling frequency and socio-demographic variables are displayed in Table 6. Female cyclists from the Netherlands were more likely to report using the bicycle for taking children to/from school, for shopping-entertainment, and for personal business (Hypothesis 4). Male cyclists from the UK were more likely to commute/travel to or from work (Hypothesis 6). In addition, male cyclists from the Netherlands were more likely to use the bicycle for leisure-training (Hypothesis 5).

We then used ordinal regression, controlling for cycling frequency and socio-demographic variables, to compare female and male cyclists crash exposure. Analysis highlighted that male cyclists were more likely to report having had an accident so severe that they had to see a doctor or were taken to a hospital, b = 0.48 (95% CI = 0.18, 0.79), SE = 0.16, p = .002, and having had an accident were their bike was damaged, b = 0.33 (95% CI = 0.21, 0.45), SE = 0.06, p < .001, confirming Hypothesis 7. The test of parallel lines revealed that in both ordinal regression analyses the assumption that the parameters are the same for all categories were reasonable, $\chi 2(22) = 30.09$, p = .116 and $\chi 2(22) = 19.90$, p = .589, respectively. We repeated both ordinal regression analyses to test potential interaction between gender and countries. All the interactions effects were not significant, indicating the relationship between gender and having had an accident did not significantly vary by country.

### 2.2.3. Discussion

The primary objective of this Study 2 was to assess gender differences in attitudes towards cycling, bicycle use and cycling crash in a sample of regular cyclists. To account for different social environments, we performed this investigation in six distinguished European countries, each with diverse cycling cultures.

In line with our expectations, results showed support for Hypothesis 1. Indeed, in our sample of regular cyclists, gender differences in attitudes towards cycling, albeit significant, were small or non-existent in terms of effect size. In particular, it was not possible to observe significant gender differences in perception of mobility benefits of cycling. Nevertheless, we found gender differences in personal benefits of cycling; females were more likely than males to perceive cycling as a practical and convenient mean of transportation. Previous studies have suggested that male cyclists are more likely to report fewer barriers or constraints to cycle and more positive attitudes to cycling compared to women (e.g. Akar et al., 2013; Dickinson et al., 2003; Emond et al., 2009; Garrard et al., 2012). However, unlike the current study, the samples used were indicative of the general population. It is possible to argue that such results were influenced by the male group's higher probability of including more regular cyclists than their female counterparts. In accordance with the self-perception theory

(Bem, 1967) these differences and constraints not only decrease or even disappear when considering only regular cyclists, but it would also appear that women perceive greater personal benefits when cycling compared to male cyclists.

Results did not show significant gender differences in reported ratings of the cycling infrastructure. Nevertheless, female cyclists perceived higher levels of discomfort than males on roads without bicycle lanes. This finding reinforces evidence from previous studies that show that female cyclists, compared to male cyclists, are more likely to be concerned about safety issues when cycling in mixed traffic (Aldred et al., 2016; Beecham & Wood, 2014; Garrard et al., 2012; Heesch et al., 2012; Krizek et al., 2005). In addition, our results revealed that females reported higher levels of risk perception of cycling than males, in agreement with previous research (Aldred et al., 2016; Beecham & Wood, 2014; Frings et al., 2012; Garrard et al., 2012; Griffin & Haworth, 2015; Heesch et al., 2012; Krizek et al., 2005). Given a higher reported cycling risk perception among regular female cyclists, we argue that these findings are not specific to cycling but might be a function of gender differences in risk perception in different domains. Previous findings on risk perception suggest that males and females tend to differently perceive risks (e.g. DeJoy, 1992; Flynn et al., 1994; Gustafson, 1998). Gustafson (1998) suggests that these differences are related to the traditional social roles of females, as care providers and nurturers, which causes women to perceive more risks to health and safety than men. This link could be a possible explanation for the differences in risk perception found in the present study. On the other hand, men traditionally identify with the role of income earners and hence tend to perceive a higher level of economic risks than women. In contrast, their perceptions of risk to health and safety are lower than females. The tendency of males to perceive lower risk than females across different types of hazards was identified by Flynn et al. (1994). Authors noticed that males in the United States showed significantly lower risk perception than females (regardless of ethnicity). This phenomenon is also known as the white male effect and is strictly connected to the privileged position of this demographic group in society. Finucane et al. (2000) identified white males' socio-economic resources, sense of control, and cultural worldviews as underlying factors of white male effect. Nevertheless, the validity of white male effect was cast in doubt in later studies suggesting that in countries with higher gender equality (e.g. Sweden) there is no significant difference between men and women in risk perception (Olofsson & Rashid, 2011).

Regarding cycling trip purpose, female cyclists from the Netherlands were more likely to use the bicycle for shopping or entertainment, personal business, and taking children to or from school and less likely to cycle for recreation or sport compared to the male counterparts. This finding suggests that Dutch women act in accordance with their traditional gender role (Beall, 1993; Garrard

et al., 2012; West & Zimmerman, 1987) when it comes to bicycle use, focusing more on care for household and offspring. However, the most interesting finding was that there were no differences in bicycle use related to gender in other countries. We could speculate that the influence of traditional gender role norms that were observed in the Netherlands was due to Dutch regular-cyclists resembling more the Dutch general population. At the same time, regular cyclists in the other countries may belong to subcultures that appear to be less affected by traditional gender role norms. In our sample, female cyclists were not more likely to use the bicycle for visiting family and friends than males, which seems to contrast with traditional gender roles. A possible implication of this results is that social activities are neither typically female nor male and therefore are not part of roles attributed to gender. However, we did not find differences in commuting cycling except for the United Kingdom. A previous study showed that male cyclists are more likely to use the bicycle for commuting to/from work (de Geus et al., 2014). Our findings suggest that this difference may reflect less bicycle use among women. Indeed, when considering regular cyclists, this difference disappears, at least in most countries.

Furthermore, we did not find significant gender differences in cycling for recreation or sport (except for the Netherlands). While competitive cycling might be more prevalent among males than among females, among female regular cyclists, recreation or sports cycling is as frequent as among regular male cyclists. Moreover, there is a wide range of recreational cycling activities, including slow-paced bicycle rides, for instance, around a park. We propose, also basing on previous literature, that increasing regular bicycle use could be a feasible solution to reduce the patriarchal characteristics of recreation or sports cycling in Western countries (e.g. Adams et al., 2010; Bryson, 1987; Connell, 1995; Dunning, 1986; Koivula, 1999; Wellard, 2002). Additionally, it could be that women were increasingly interested in cycling for recreation or sport due to its physical health benefits such as weight management and smoking cessation as well as its mental health benefits, such as stress and depression levels reduction and relieves of premenstrual syndrome-related symptoms (Garrard, 2003). As a matter of fact, indoor cycling (i.e. exercising on a stationary bicycle) is prevalent among women (Szabo et al., 2015). Indeed, in the present study, women were more likely to endorse the view that cycling conveys benefits for the person.

Findings of Study 2 also agree with results reported by previous authors (Bíl et al., 2010; Eluru et al., 2008; Marín Puchades et al., 2017; Prati, De Angelis, Marın Puchades et al., 2017; Prati, Pietrantoni & Fraboni, 2017), suggesting that gender differences in the likelihood of being involved in bicycle crashes remain among regular cyclists. Researchers have taken many different variables into account to explain the gender difference in the likelihood of being involved in bicycle crashes

such as speeding, risk perception, attitudes towards road safety, risky driving behaviours, knowledge and skills (Cobey et al., 2013; Cordellieri et al., 2016; Johnson et al., 2011; Schantz, 2017; Useche, Montoro, Alonso et al., 2018).

While we did not find significant gender differences in perceptions and attitudes towards cycling across the six European countries, we did find significant country related differences in perceptions and attitudes towards cycling. It is of particular interest that results of the present study highlighted lower scores on mobility and personal benefits of cycling among Dutch cyclists. While this could be considered nonsensical, it is still possible to argue that in the Netherlands many people opt to use the bicycle mostly because (1) cycling is part of the Dutch national identity, (2) many formal and informal social norms present in the Netherlands, and (3) the quality and provisions of bicycle infrastructure (e.g. Haustein & Nielsen, 2016; Kuipers, 2012; Pucher & Buehler, 2008). Thus, it is likely that Dutch cyclists may cycle for other reasons than for environmental or personal benefits. Indeed, our results showed that, compared to Dutch cyclists, Italian and Spanish cyclists tend to report higher scores for personal benefits and mobility benefits of cycling, while reporting lower ratings of infrastructure quality and provisions. It seems thus likely that environmental or personal benefits are more valued among regular cyclists in emerging cycling countries (e.g. Italy) than in established cycling country (e.g. the Netherlands) because they tend to lack other motivational forces (e.g. quality and provisions of bicycle infrastructure or pro-bicycle social norms).

Hungarian cyclists reported the highest scores on perceived discomfort both for cycling on the road with and without cycling lanes, as well as reporting the lowest risk perception related to cycling. Reports and studies provided evidence that, lately, many investments have been made to improve cycling network and infrastructure in Hungary's major cities such as Budapest and Debrecen (e.g. Kerényi & Bencze-Kovács, 2012; Kosztin et al., 2017). Haustein and Nielsen (2016), for instance, connected the large share of utilitarian cyclists found in Hungary to such investments. Our study may suggest that those efforts mostly contributed to curbing cyclists' risk perception, while not generating an appreciable impact on cycling comfort in general. The lowest discomfort ratings were reported by cyclists from the United Kingdom which might be due to the remarkable investments in cycling in the last decade as part of the National Cycling Cities and Towns Programme (Chatterjee et al., 2013). Future studies could test this idea further by comparing different interventions and type of infrastructure provided in Hungary and U.K. in order to shed light if and which element has a more significant impact on cyclist's comfort and risk perception.

There are some important caveats to the study that deserve mention. First of all, the cross-sectional design of the study limits the causal inferences that can be made. Secondly, the applicability

to some segments of the population was limited by the requirement for e-mail and Internet access. In addition, the generalizability of the findings is limited because the study population is self-selective (i.e. online panel). Lastly, the survey data are based on self-reported information and, therefore, are open to recall bias and reporting errors.

## 3. Focussing on Cyclists' Safety

The third section of the present thesis aims to deepen the focus on bicycle safety. Cyclists are in fact considered minority road users (Prati, Marìn Puchades & Pietrantoni, 2017) and cyclists are overrepresented in road injuries statistics, highlighting concerns (Heinen et al., 2010; Schepers, Hagenzieker, Methorst et al., 2014). As safety considerations represent a relevant barrier to cycling and its promotion (Jacobsen & Rutter, 2012) researchers have begun to focus their attention on cyclists' accidents and their contributory factors (Prati, Marìn Puchades, De Angelis et al., 2018).

### 3.1. STUDY 3: Gender differences in cyclists' crashes and related contributing factors

In Study 3, we shifted our attention to gender differences in bicycle crashes, focusing on factors that can contribute to cyclists' risk of suffering a severe injury or a fatality. We have put particular attention to assess characteristics related to the type of crashes (the type of collision and opponent vehicle), the infrastructure (road type and type of road segment), the environment (season, road surface condition, and weather), and time period (time of the day, day of the week).

A number of studies have addressed the relationship between gender, crash rate and behaviour of road users (Al-Balbissi, 2003; Cordellieri et al., 2016; Factor et al., 2008; Massie et al., 1995; Pulido et al., 2016; Rhodes & Pivik, 2011; Santamariña-Rubio et al., 2014; Tom & Granie, 2011; Williams & Shabanova, 2003). Nevertheless, there are conflicting results regarding the nature of these gender differences (Santamariña-Rubio et al., 2014). Most of those studies focused on gender differences in crashes without taking into account the specific characteristics of each road users typology (e.g. drivers of lorries, cars, and two-wheeled motor vehicles, cyclists, pedestrians) focussing primarily on car drivers (e.g. Elvik et al., 2009). There has been little research examining gender differences in cycling crashes (e.g. Cordellieri et al., 2016). This is a possible reason why evidence on the matter is still inconsistent. In the present thesis, we have already provided arguments to explain that cyclists are specific road users that are not comparable to other road users' categories. Cyclists peculiarities, compared to other motorised road users, can be summarised as follows (Prati, Marín Puchades, & Pietrantoni, 2017): they (1) lack physical protection; (2) are less visible and conspicuous; (3) are more affected by road surface irregularities; (4) are more exposed to the risk of serious injuries and death when incurring in collisions with motor vehicles due to the differences in

mass and speed (Haworth & Debnath, 2013; OCDE/OECD, 1998; Wegman et al., 2012). In addition, cyclists are not treated as legitimate road users in many countries due to historical, social, and cultural factors (Prati, Marín Puchades, et al., 2017).

In Study 3, we aim to deepen our knowledge about gender differences in characteristics of bicycle crashes as well as addressing possible interplay with crashes outcome severity (i.e. severe versus fatal injury) for the cyclist. In the present study, we used a sample of routinely collected road safety data from Italy. Italy can be considered a country with a low-cycling culture or an emerging cycling culture (Aldred & Jungnickel, 2014; Oosterhuis, 2016). In comparison to cyclists in other European countries, as it was also highlighted in Study 1 and 2, Italian cyclists are more likely to describe positive attitudes towards cyclists but also the lowest ratings on infrastructure quality and provisions. According to the Special Eurobarometer 422a – Quality of transport (European Commission, 2014), in Italy 8% of women and only 4% of men report using the bicycle as the primary mode of transportation. Nevertheless, data on competitive and recreational cyclists in Italy highlights that the proportion of men cyclists amount to 2.4 per 100 inhabitants, while among women cyclists it is only 0.4 per 100 inhabitants (ISTAT, 2005, 2017).

We introduced general hypotheses basing on previous evidence in other contexts but is necessary to mention that the present study is mainly exploratory. In general, the contingent risk of suffering an injury while participating in traffic is higher for women than for men (Elvik et al., 2009). However, evidence shows that men are at a higher risk of experiencing a deadly accident (Factor et al., 2008; Massie et al., 1995; Pulido et al., 2016; Santamarina-Rubio et al., 2014; Sospedra-Baeza, 2018). Besides, research suggested that drivers' age moderates gender differences in crash involvement. Mean crash rate is lower for young women drivers compared to young male drivers, while the ratio is inverted for drivers above 30 years old (Elvik et al.,2009).

Concerning the Italian context, to our knowledge, there are only a few studies that provide partial evidence about gender differences in cycling. For instance, authors found gender to be one of the main predictors of bicycle helmet use in Italy, with males having a higher propensity to use it (Popa et al., 2017). Another study, which focused on gender differences in commuting (Cristaldi, 2005), provided evidence that Italian women are more likely to commute on foot or by bike than men (especially in the North of Italy) and observed that commuting patterns of Italian women tend to align with those of first-world countries. A cross-sectional study investigating risky behaviours and crash involvement in a sample of Italian cyclists found men to be at greater risk of incurring in near-crashes and actual crashes than female (Marín-Puchades et al., 2017). Nevertheless, the authors couldn't find significant gender differences in unsafe cycling behaviours. A study based on Italian crash data

highlighted that male cyclists tend to be at greater risk of fatal injury than female cyclists (Prati, Pietrantoni & Fraboni, 2017) and that gender differences heighten in urban municipal roads. It is also worth to mention that a similar study on a Spanish sample, highlighted that the risk of incurring in a severe or fatal crash is significantly higher among men cyclists than among women cyclists (Santamarina-Rubio et al., 2014). However, the authors were not able to address whether an interaction between sex and age of cyclists in fatality risk exists, mainly due to the low numbers of cyclists injured. Study 3 thus aims to explore gender differences among cyclists in fatality risk, while taking into account potential age-related effects. Based on the available research, we, therefore, postulate that the risk of suffering a fatal injury is higher for young men cyclists than for young women cyclists (Hypotheses 1).

It is also important to mention that gender differences in cycling crashes may be related to differences in cycling patterns which are, to a certain extent, a function of cycling culture or, more specifically, utilitarian cycling culture (Garrard et al., 2012). As we previously explained in the present thesis, the traditional sexual division of labour (e.g. related to housework and caring duties) influences women's participation in transport cycling (Prati, 2017). As we remarked in Study 2, gender differences in mobility patterns of cyclists may be related to gender differences in cyclists' crashes. It is thus essential to consider previous evidence on gender differences in cycling patterns. In details, evidence showed that women cycle shorter distances than men (Heinen et al., 2010), which is probably connected to the fact that female cyclists have been found to reside at a lower mean distance of from the city centre than male cyclists (Garrard, Rose, & Lo, 2008). Those studies suggested that women cyclists tend to use the bicycle mainly in the urban context. As a consequence, it is reasonable to expect that women cyclists, compared to men cyclists, may be more likely to be involved in a crash in the urban context (Hypothesis 2). Also, people generally tend to cycle more in daylight conditions than in duskiness or darkness, and this difference heightens in women cyclists compared to men cyclists (Bergstrom & Magnusson, 2003; Heesch et al., 2012). Thus, we hypothesise that men cyclists might be less likely to incur in a crash during daytime (Hypothesis 3). As discussed in study 2, when addressing gender differences in bicycle use for commuting, Cristaldi (2005) found that Italian women tend to commute by bike more than men and suggested that the commuting patterns of Italian women will, in general, line up with those of Western countries. Another study showed instead that women cyclists are more likely to use the bicycle for non-commuting trips such as travelling with children and shopping (Garrard et al., 2012), and that men are overrepresented among Italian competitive and recreational cyclists (ISTAT, 2005, 2017). In respect to sport and recreational cyclists, there is ample evidence that they account for the higher number of bicycle trips on weekends compared to weekdays (Amoros et al., 2011; Billot-Grasset et al., 2014; Spotswood et

al., 2015). According to evidence here presented, it could be hypothesized that men cyclists, compared to women cyclists, will have a higher risk of incurring in crashes during weekends (Hypothesis 4). Since sport and recreational cyclists tend to ride on rural roads and during summer (Amoros et al., 2011; Blaizot et al., 2013; Buning et al., 2019), we expect that they will be more likely to be involved in crashes during summer, compared to women cyclists (Hypothesis 5).

Again, gender roles and cultural factors may play a role in defining gender differences in the incidence of road risky behaviours (i. e. behaviours that can possibly be a contributing factor to crashes, such as speeding, distracted cycling or cycling under the influence) and violation of road regulations among cyclists (Santamariña-Rubio et al., 2014). A possible theoretical explanation can be found in the concept of hegemonic masculinity proposed by Connel (1995). The author refers to how and why men maintain dominant social roles over women, and other "feminine" identities, through practices that legitimize powerful men's dominant position. Ideals of hegemonic masculinity presumably encourage the development of a traditional heterosexual masculine identity which is associated with the adoption of a specific set of behaviours. Among those behaviours that are associated with the masculine identity, we can find risky driving style. At the same time, safety skills increase as a function of femininity (Özkan & Lajunen, 2005, 2006). Moreover, gender differences in road safety attitudes and risk perception (Cordellieri et al., 2016; Frings et al., 2012; Rhodes & Pivik, 2011) might as well explain the higher frequency of risky behaviours or violations in male road users, when compared to their female counterparts (e.g. Al-Balbissi, 2003; Feenstra et al., 2011; Nallet et al., 2010; Özkan & Lajunen, 2006; Rhodes & Pivik, 2011; Tom & Granie, 2011; Turner & McClure, 2003). In a cross-sectional study on 1064 cyclists from Latin America, North America and Europe, authors found gender influencing the onset of cyclists' risky and protective behaviours. Age, cycling intensity, self-reported knowledge of traffic rules, psychological distress and risk perception were found to differently predict the riding behaviours of male and female cyclists (Useche, Montoro, Alonso et al., 2018). Preliminary evidence suggests that violations and risk-taking behaviours are more frequent among male cyclists than female cyclists. Specifically, gender was found to affects scores on the Cycling Behaviour Questionnaire (CBQ) regarding traffic violations, with male cyclists reporting higher values than their females' counterparts (Useche, Montoro, Tomas et al., 2018). Furthermore, male cyclists have been found to engage more often than females in non-compliant behaviour such as ignoring traffic signals (Bernhoft & Carstensen, 2008; Johnson et al., 2013; Johnson et al., 2011; Yan et al., 2011), cycling without a helmet, and cycling without appropriate lights in the night (Cobey et al., 2013). We thus hypothesize that compared to female cyclists, male cyclists are more likely to be involved in road crashes in which a cyclists' violation of rules is committed (Hypothesis 6).

Addressing culture and, in particular, the notion of hegemonic masculinity can be useful for formulating a hypothesis on gender differences in risky behaviour. Notably, it is possible to extend this notion to the type of interactions between road users. Hegemonic masculinity is built upon the belief of male gender superiority over the others (Connell, 1995). As we argued in Study 2, the cultural characteristics of hegemonic masculinity might prompt specific road users' behaviour. For instance, individuals belonging to a majority group (i.e. motorists), when interacting with a minority (i.e. sharing the road with cyclists), might exhibit disrespectful or risky behaviours. Magaraggia (2013) showed that although hegemonic masculinity is not present in the majority of Italian men, it still is normative. Even though research showed that drivers tend to be more cautious when overtaking cyclists with feminine characteristics (Walker, 2007), we could still claim that the normative effect of hegemonic masculinity is prevalent in the Italian context (Magaraggia, 2013). Consequently, we postulate that women cyclists are relatively more likely than male cyclists to be involved in crashes in which the opponent vehicle did not comply with the right of way rules (Hypothesis 7).

Data from a sample of 4596 UK cyclists showed that, compared to men, women are overrepresented in the number of fatal crashes involving heavy goods vehicles (Frings et al., 2012). A closer look at fatal bicycle-heavy goods vehicles crashes reveals that many of them happen at crossroads, where motorised vehicle drivers turn. Heavy good vehicles have many blind spots, and it is often difficult for drivers to spot bicycles attempting to overtake them on the nearside, particularly at junctions. In this situation, there is a sizeable risk that the cyclists remain undetected by the truck driver and thus gets run over (Niewoehner & Berg, 2005). These situations are labelled in literature as Righ-hook scenarios (or Left-hook scenarios for left-side driving countries). Preliminary evidence suggests that, on the one hand, women cyclists tend to report higher cycling risk perception than men (Frings et al., 2012). However, on the other hand, they were more likely to belittle risks entailed by overtaking heavy-goods vehicles (Frings et al., 2012). Accordingly, it could be hypothesized that the type of crash will be influenced by gender, with women being more likely to incur in crashes with heavy-goods vehicles (Hypothesis 8). Lastly, a relatively recent study using video-based data to investigate bicycle-vehicle interactions at junctions, found that women were more likely than men to be involved in dangerous conflicts with motorised vehicles at intersections (Stipancic et al., 2016). Hence, our last hypothesis states that women cyclists will be more likely to incur in bicycle crashes at junctions (Hypothesis 9).

### 3.1.1. Materials and Methods

#### Data

To address the objective of Study 3, we used routinely recorded crash data collected by the Italian National Institute of Statistics (ISTAT). The ISTAT dataset is built on aggregated data from various private contributors and public institutions, which collect details about all road crashes on Italian roads: Italian Ministry of Transport and Infrastructure, local Municipalities, National Police agencies, Italian Automobile Club, as well as the ISTAT itself. The dataset includes information on all means of transportation and every (reported) type of crash. Data from ISTAT are publicly accessible upon application to a formal request procedure. Before allowing access to any actor, ISTAT fully anonymizes the data.

We selected only road crashes that occurred in the three years between 2011 and 2013, leaving us with a total number of 575,093 road crashes. This specific time interval has been selected for the following reasons: (1) the 2013 database was the most recent publicly available at the time of the study, (2) the selected time-span comprised a sufficiently large number of crashes, and (3) allowed us to control for changes in traffic regulations. The latest amendments to the Italian national traffic laws, which involved minor changes addressing bicycle use, dated back to 2010 (Law 29/7/2010 n. 120). According to the objective of the present study, we extracted from the dataset a total of 49,621 crashes in which at least one cyclist ended up injured or killed. How ISTAT dataset accounted for the severity of crashes was by differentiating between crashes that resulted in injuries or fatalities (within 30 days from the crash).

To explore gender differences in cyclists' crashes, we compared the extracted crash data basing on the following road and crash characteristics: type of road, road segment, type of opponent vehicle, opponent vehicle manoeuvre, cyclist's manoeuvre, type of collision, time of the day, day of the week, season, road surface condition, and weather. Regarding the type of road, the Italian traffic laws define roads crossing urban communities with fewer than 10,000 inhabitants as urban national, urban regional, and urban provincial roads. Internationally, those types of road are generally addressed as national, regional, and provincial road, respectively.

#### Statistical analysis

We used a sequence of chi-square tests to appraise gender differences in bicycle crashes. To account for multiple testing, we used the Bonferroni adjustment procedure, and only probability values equal to or less than .005 were considered significant. To discern the nature of the association, we conducted a cell-by-cell comparison of observed and estimated expected frequencies. Precisely,

when the data conform to a 2 × 2 table, we reported the odds ratio. In the case of a 2 × k table, we calculated standardized residuals. Calculating standardised residuals allow identifying those specific cells making the most significant contribution to the chi-square test finding (Agresti, 2013). Standardized residuals are z-scores. Thus, if the value exceeds ±1.96 then the null hypothesis is rejected at the α = .05 significance level. If the value exceeds ±2.58 then the null hypothesis is rejected at the α = .01 significance level. If the value exceeds ±3.29 then the null hypothesis is rejected at the α = .001 significance level instead. We applied a Bonferroni adjustment to the z critical of 1.96 to take into account the number of cells in the contingency table, as suggested in previous studies (MacDonald & Gardner, 2000).

While we used Chi-square analyses to test all the hypotheses, an exception was made for Hypothesis 1 since it involved three variables. To investigate gender differences among cyclists fatality risk, taking into account age-related effects, we employed a three-way log-linear analysis (gender X severity X age).

We acknowledge that chi-square and log-linear analysis do not allow to make an absolute distinction between dependent and independent variables. However, basing on the proposed theoretical background, gender was considered the independent variable. In chi-square analyses, each crash characteristic was considered as the dependent variable. In the three-way log-linear analysis, we considered the outcome of the crash (non-fatal versus fatal injury) as the dependent variable, while age was considered as the moderating variable.

To determine effect sizes for chi-square tests of independence, when the data conformed to a 2 × 2 table we used the phi coefficient (Φ), while we used Cramer's V in case of a 2 × k table. Phi values and Cramer's V values (in a 2 × k table), of .10, .30, and .50 correspond to an effect size that could be described as small, medium, and large, respectively (Cohen, 1988). In case of a 2 × 2 table, we calculated odds ratios as well. According to Rosenthal (1996) we used the following qualitative size categories for odds ratios: about 1.5 = small effect (or weak association), about 2.5 = medium (or moderate), about 4 = large (or strong), about 10 = very large (or very strong).

### 3.1.2. Results

To test Hypothesis 1, which addressed differences between male and female cyclists' fatality risk while also accounting for age-related effects, we conducted a three-way log-linear analysis (gender X severity X age). The analysis showed that the interaction between gender, severity and age was not significant, v2 (5) ¼ 1.56, p ¼ .906. Nevertheless, the relationship between gender and severity proved to be significant, v2 (1) ¼ 85.76, p < .001, U ¼ –.04. The odds of fatal injury were

2.33 times higher among men cyclists compared to women, as suggested by odds ratios (0.43, 95% CIs ¼ 0.36, 0.52). These findings partially support Hypothesis 1, men cyclists are at a higher risk of suffering a fatal crash than women, regardless of their age.

Regarding Hypothesis 2, gender was associated with types of road, v2 (2) ¼ 984.84, p < .001, V ¼ .14. Standardized residuals in S1 Table indicated that the odds of incurring in a crash on urban roads were more likely among women cyclists, while the men cyclists were more prone to have a crash on rural roads and on urban provincial, regional and national roads. Thus, Hypothesis 2 was supported.

Concerning Hypothesis 3, gender was related to the time of the day in which the cycling crash took place, v2 (3) ¼ 223.48, p < .001, V ¼ .07. Standardized residuals in S2 Table indicated that men cyclists were more likely to be involved in a crash during the evening or late night, while women cyclists were more likely to have a crash during the daytime. Thus, Hypothesis 3 was supported.

Women and men cyclists had a different likelihood of being involved in a crash during the weekdays and weekend (Hypothesis 4), v2 (1) ¼ 285.85, p < .001, U ¼ –.08. Specifically, odds ratios (0.66, 95% CIs ¼ 0.63, 0.69) indicated that the odds of a cycling crash during the weekend were 1.52 times higher among men cyclists compared to women. Therefore, Hypothesis 4 was supported.

Results for Hypothesis 5 indicated that gender was associated with the season in which the cycling crash took place, v2 (3) ¼ 19.85, p < .001, V ¼ .02. Standardized residuals in S3 Table revealed that women cyclists were more likely to report a crash during autumn, while men cyclists during summer. Therefore, Hypothesis 5 was supported.

We conducted a chi-square goodness-of-fit test of the manoeuvre of the cyclist involved in the crash to examine gender differences in violation of regulations (Hypothesis 6). The test showed that the manoeuvre of the cyclist involved in the crash differed by gender v2 (9) ¼ 48.68, p < .001, V ¼ .03. Standardized residuals in S4 Table indicated that men cyclists were more likely to have a crash while overtaking and speeding. Therefore, this finding provided support for Hypothesis 6.

The type of manoeuvre of the opponent vehicle was different according to the gender of the cyclist involved, v2 (6) ¼ 31.58, p < .001, V ¼ .04. Standardized residuals in S5 Table indicated that women cyclists had a greater odds of having a collision with a vehicle turning right, ignoring a stop sign, or red traffic light. This finding supports Hypothesis 7 that women cyclists are more likely to be involved in crashes in which the opponent vehicle did not respect the priority rules.

Concerning Hypothesis 8, gender was related to type of opponent vehicle, v2 (6) ¼ 31.58, p < .001, V ¼ .03. Standardized residuals in S6 Table showed that women cyclists were more likely to have a collision with a car and a bus. Men cyclists were more likely to be involved in collisions involving multiple vehicles and in crashes where no other road user was involved. This finding failed to support Hypothesis 8.

Finally, regarding Hypothesis 9, the relationship between gender and type of road segment was significant, v2 (2) ¼ 23.85, p < .001, V ¼ .02. Standardized residuals in S7 Table indicated that women cyclists were more likely to have a crash at crossroads, while men cyclists were more likely to have a crash in other road sections. There were no gender differences for crashes at roundabouts. Therefore Hypothesis 9 was supported.

### 3.1.3. Discussion

The fundamental objective of Study 3 was to investigate differences in crashes characteristics between male and female cyclists. To do so, we analysed routinely recorded crash data gathered from the ISTAT. Past studies examined gender differences in crash rates and driving behaviour of road users (Al-Balbissi, 2003; Cordellieri et al., 2016; Factor et al., 2008; Massie et al., 1995; Pulido et al., 2016; Rhodes & Pivik, 2011; Santamarina-Rubio et al., 2014; Tom & Granie, 2011; Williams & Shabanova, 2003). Nonetheless, studies that would focus solely on the population of cyclists are lacking, and the present study attempts to fill in this gap.

First, consistent with previous research on road users (Al-Balbissi, 2003; Cordellieri et al., 2016; Factor et al., 2008; Massie et al., 1995; Pulido et al., 2016; Rhodes & Pivik, 2011; Santamarina-Rubio et al., 2014; Tom & Granie, 2011; Williams & Shabanova, 2003), we found that men cyclists are 2.33 times more likely to suffer a fatal injury than women (Hypothesis 1). Concerning Hypothesis 1, however, the results do not suggest any interaction between age and gender in determining the severity of cycling crashes (Elvik et al., 2009). Regardless of age, men cyclists are more likely to be involved in a fatal crash compared to women. These gender differences could be explained by social and cultural factors that account for gender differences in mobility patterns, risk perception, attitudes and risky behaviours (e.g. Al-Balbissi, 2003; de Winter & Dodou, 2010; Nallet et al., 2010; Ozkan & Lajunen, 2006; Prati, 2018; Rhodes & Pivik, 2011; Tom & Granie, 2011). Concerning mobility patterns, we found that men cyclists are more likely to be involved in crashes in rural areas (Hypothesis 2) and previous research documented that, in Italy, the risk of fatal injury is higher in rural areas than in urban areas (Prati, De Angelis, Marın Puchades et al., 2017; Prati, Pietrantoni & Fraboni, 2017). In the present study, we also found some evidence of systematic differences across

gender in risky behaviours and violations (Hypothesis 6). Compared to women, men cyclists were more likely to be involved in a crash while travelling too fast and overtaking. Sport cycling generally means riding faster (Blaizot et al., 2013), and thus it is possible to expect more frequent and more severe injuries in the population that practices it. Higher speed presents an increased risk of severe bicycle-motorised vehicle conflict, which may, in turn, explain a higher rate of fatal crashes among men cyclists (Stipancic et al., 2016). Consistent with these findings, in the present study, men cyclists were more likely to be involved in a crash while travelling at high speeds (S4 Table). However, no evidence of gender difference was found for the following violations: not keeping a safe distance, ignoring stop signs or red traffic lights, not respecting the right of way, and driving in a forbidden direction or on opposite sides of the road. The lack of difference may suggest that women are closing the gap to some extent. There is evidence that some groups of women drivers (young women in particular) were found to be increasingly involved in risk-taking behaviour and violations (Romano et al., 2008).

Finally, men are highly over-represented among sport and recreational cyclists in Italy (ISTAT, 2005, 2017). As such, they are more likely to ride on rural roads (Hypothesis 2), on weekends (Hypothesis 4) and during the summer (Hypothesis 5). Indeed, our results reveal a higher occurrence of crashes among men cyclists on weekends and during the summer period. The severity of bicycle crashes results higher on rural roads than on urban roads, which may also be an explanation for a higher occurrence of fatal crashes among men (Boufous et al., 2012; Moore et al., 2011; Prati, De Angelis, Marìn Puchades et al., 2017; Prati, Pietrantoni & Fraboni, 2017). Ideals of hegemonic masculinity shape the patriarchal character of sport in Western countries (e.g. Adams et al., 2010; Bryson, 1987; Connell, 1995; Dunning, 1986; Koivula, 1999; Wellard, 2002) and this can explain why men cyclists are over-represented among sport or recreational cyclists and, in turn, are more likely to be involved in a crash on rural roads, on weekends, and during summer.

As already mentioned, we presume that such gender differences in mobility patterns, risk perception, attitudes and risky behaviours derive from a socially constructed ideas about masculinity and femininity that are specific to the Italian culture (Beall, 1993; West & Zimmerman, 1987). The development of a traditional masculine identity that stems from ideals of hegemonic masculinity is indeed associated with risky behaviours and violation of regulations (Santamarina-Rubio et al., 2014). Moreover, the concept of hegemonic masculinity may also present a threat to women cyclists in certain situations. In the present study, consistent with the cultural norms of hegemonic masculinity in the Italian context (Magaraggia, 2013), we found that women cyclists are more likely to be involved in road crashes where the opponent vehicle did not respect the priority rules (Hypothesis 7). Such

results suggest that in societies with high masculinity, it may be deemed less necessary to respect the priority rules when the cyclist is a woman.

Second, women cyclists are more likely than men to be involved in crashes at crossroads (Hypothesis 9), and in crashes due to a right-turn (nearside turn) manoeuvre of the opponent vehicle (S5 Table). The former finding is consistent with the results of a previous study suggesting that women cyclists are more likely than men cyclists to be involved in dangerous conflicts with vehicles at crossroads (Stipancic et al., 2016). Such crashes tend to take place in urban areas where the density of crossroads is generally higher. It is also possible that the finding that women are more involved in crashes with bus and cars is related to the fact that women cycle more in urban areas. Although the expectation that buses are more frequent in the urban road is reasonable, there is no evidence supporting this claim; therefore, future research is needed to investigate the difference in traffic vehicles between urban and rural environment.

Third, women cyclists were more likely to have a collision with a car and a bus but not with a heavy goods vehicle (Hypothesis 8) as was predicted based on the findings of Frings et al. (2012). It is important to mention that the probability of a collision with heavy-goods vehicles is influenced by the portion of the road in which the cyclists is riding, the percentage of trucks present in the traffic at a specific place and time and by the frequency of intersection in the cyclists' journey as well.

Third, women cyclists were more likely to have a collision with a car and a bus but not with a heavy goods vehicle (Hypothesis 8) as was predicted based on the findings of Frings et al. (2012). It is essential to mention that the probability of a collision with heavy-goods vehicles is influenced by the portion of the road in which the cyclists is riding, the percentage of trucks present in the traffic at a specific place and time and by the frequency of intersection in the cyclists' journey as well.

The results of the present study should be considered in light of its research limitations. A limitation is that the ISTAT database does not provide exposure data (i.e. difference on bicycle use across gender). For instance, the number of kilometres ridden by bicycle may be higher for men than for woman, and this may contribute to the fact that the men cyclists are more likely to suffer a fatal injury than women cyclists. To account for the lack of exposure data, we have considered data on gender differences in bicycle use from other research. Another limitation is that the ISTAT database does not provide information that indicates whether a violation was recorded. Therefore, we calculated the injuries, and the rate of injury is unknown. However, it is essential to note that the ISTAT database provides the most complete and reliable database of road crashes in Italy.

## 3.2. STUDY 4: Affective and Instrumental Attitudes, Evaluation of Motorist Behaviour and E-Bike Use as Predictors of Bicycle Crash Involvement

In Study 4 we aim to deepen the focus on possible factors contributing to cycling accidents, explicitly focusing on instrumental and affective attitudes toward cycling and cyclists' perceptions of motorists' behaviour. Furthermore, given the current rise in e-bike use in many European countries, Study 4 proposes to assess e-bike use and underlying differences in riding behaviour as a possible contributing factors to cyclists' crash involvement.

As extensively described in the present thesis, past research has highlighted the importance of instrumental and affective factors in work and leisure journeys among regular cyclists (Anable & Gatersleben, 2005). In summary, instrumental attitudes concern to the utility or functionality of cycling, whereas affective attitudes concern the emotional experience derived from cycling. However, to our knowledge, no study has investigated whether the importance that cyclists attach to various instrumental and affective journey attitudes is associated with bicycle crash involvement and severity. Specifically, instrumental attitudes refer to a sense of predictability, safety, and convenience when using the bicycle. We theorized that instrumental attitudes might be associated with an increased risk of bicycle crash (Hypothesis 1) because cyclists endorsing instrumental attitudes see traffic situations as more controllable and predictable. This could possibly lead cyclists in underestimating risks related to cycling. Previous research showed a significant association between risk perception and the likelihood of incurring in a crash, which was fully mediated by cyclists' self-reported risky behaviours within a five years' timespan (Useche, Alonso, Montoro et al., 2019). Furthermore, studies among cyclists revealed that overconfidence in cyclists' skills is associated with a higher risk of near misses (Puchades et al., 2018) and with relatively lower risk perception of dangerous traffic situations, such as committing a violation (Chaurand & Delhomme, 2013; Salmon et al., 2013). Overconfidence may also lead cyclists to not avoiding traffic situations (e.g., dangerous interactions with motorized vehicles) that, otherwise, would be considered hazardous (Puchades et al., 2018). Indeed, cyclists report experiences of abuse and harassment from motorists in mixed traffic conditions (O'Connor & Brown, 2010; Heesch et al., 2011). Therefore, we expected that cyclists scoring high on affective attitudes would be less likely to report having been involved in a bicycle crash (Hypothesis 2) because they are more likely to avoid dangerous traffic situations that are unpleasant.

Research from Chataway et al. (2014) showed that cyclists in an emerging cycling city tend to report higher levels of perceived risk concerning the interaction with motorized vehicles than those in an established cycling city. Although previous research focused on the perceived risk in relation to

the interaction with motorized vehicles (Puchades et al., 2018), to date, no studies have focused on the evaluation of motorist and van/lorry driver driving behaviour among cyclists. This is of particular importance since preliminary evidence suggest that avoidance of cycling in mixed traffic conditions, even if it means cycling on a longer route, can be considered as a coping strategy to reduce exposure to mixed traffic and minimize the resulting feelings of unsafety (Puchades et al., 2018, O'Connor & Brown, 2010, Chataway et al., 2016). As we previously mentioned, collisions between cyclists and motorized vehicles account for most reported bicyclists' fatalities and serious injuries (Chong et al., 2010; Nicaj et al., 2009; Rosenkranz & Sheridan, 2003; Sze et al., 2011; Rowe et al., 1995). Thus, we postulate that the poorer the cyclists' perception of the driving behaviour of motorists and van/lorry drivers, the lower the likelihood of them suffering a severe injury (Hypothesis 3).

In the last two decades, a sharp increase in the purchase and use of e-bikes has been observed. Although research on the safety of e-bikes is still in its infancy, there is preliminary evidence suggesting that the crash risk among e-bike users is greater than that of classic-bicycle users (Fishman & Cherry, 2016). However, the magnitude of this effect is mostly unknown, and more research is required using more extensive samples of the general e-bike and classic-bicycle user population. Based on previous research (Fishman & Cherry, 2016; Schepers, Fishman, Den Hertog et al., 2014; Yao & Wu, 2012), we hypothesized that e-bike users would be more likely to report bicycle crashes than classic-bicycle users (Hypothesis 4).

We test these hypotheses in two models explaining crash severity and involvement while controlling for sociodemographic factors (i.e., gender, age, working status, country), cycling levels, type of cycling environment, and cycling purpose. There is evidence in the literature that the environment may influence the likelihood of bicycle crashes (Prati, Marìn Puchades, De Angelis et al., 2018) and that crash experiences differ according to cycling purpose (Poulos et al., 2015).

### 3.2.1. Materials and Methods

#### Procedure

In Study 4 we choose to take advantage of the extensive amount of data we already gathered in Study 1, thus using the same dataset. In summary, the procedure unfolded as follows: (1) pilot version of the questionnaire in English administered to 60 participants; (2) scrutiny of data from the pilot questionnaire led to changes of questions which produced anomalous replies; (3) the finalised version of the questionnaire was translated, sense checked by native speakers, uploaded to a customised online survey platform, and administered to 2417 participants; (4) after response collection ended, data from participants who responded with the same values within a scale or who

completed the questionnaire in a time shorter than a pre-established limit were discarded, leaving a sample of 2389 participants included in the analysis.

### Participants

As for Study 1 and 2 the dataset included 2,389 participants who made at least one cycle trip per month. Participants lived in U.K. (n = 399, 16.7%), Netherlands (n = 398, 16.7%), Spain (n = 397, 16.7%), Hungary (n = 400, 16.7%), Italy (n = 403, 16.9%), and Sweden (n = 392, 16.4%). There were 1,210 female (50.6%), 1,171 (49.1%) male, and 8 (0.3%) transgender participants. Participants from the latter group were not included in subsequent analyses because of the small sample. Concerning bicycle use, 437 (18.4%) cycled daily, 872 (36.6%) did so three or more days a week, 707 (29.7%) participants cycled 1 to 2 days a week, and 365 (15.3%) participants used a bicycle one to three times a month. An e-bike was the most frequently used type of bike by 203 (8.5%) participants. Most participants (n = 2,180, 91.3%) did not report any severe bicycle crashes in the past 2 years, whereas 129 participants (5.4%) had to see their doctor but did not need to go to the hospital, 63 participants (2.6%) had to attend hospital as an outpatient, and 17 participants (0.7%) had to stay in hospital over-night. The majority of participants (n = 1,952, 81.7%) reported having had a crash within the past 2 two years in which their bike was damaged, 367 participants (15.4%) reported one crash, 49 participants (2.1%) two crashes, and 21 participants (0.9%) reported more than two crashes.

### Measures

As described in Study 1 and 2, the instrument included questions on demographic information such as age, gender, working status, and country of residence. Other areas included information about cycling levels (i.e., we calculated the yearly trip values by multiplying the number of months in which they use the bicycle by the number of trips per months), the reasons for undertaking these cycle journeys, e-bike use, and the type of environment they make the majority of their cycle trips within (participants were asked to select one of the following options: rural, village, town, and city).

*E-bike use* was assessed using the next dichotomous question (with yes/no responses): ‘‘Is the bike you ride most frequently an electric bike?’’

To appraise *Instrumental and affective journey attitudes* in Study 4 we considered appropriate to stick to the conceptualisation proposed by Anable and Gatersleben (2005). Hence, participants’ instrumental journey attitudes were evaluated using six questions (i.e. ‘‘How far do you agree that you cycle because:” “it is comfortable?’’; “of traffic safety reasons”; “of the time savings?’’; “it

improves personal security"; "it is flexible"; "it is cheap"). Cronbach's alpha was .83. While three questions were used to measure effective journey attitudes (i.e. ''How far do you agree that you cycle because:" "it is pleasant?''; ''it is physically relaxing?''; ''it is mentally relaxing?''). Cronbach's alpha was .85. Both sets of questions had response options on a 5-point Likert scale (1 = Completely disagree to 5 = Completely agree).

To assess both *bicycle crash involvement and severity*, we used two questions inspired by Feenstra et al. (2014). To obtain a measure of exposure to severe crashes, we used one question: ''In the past 2 years while cycling, have you had an accident so severe that you had to see a doctor or were taken to a hospital?'' with the options 1 (No), 2 (Yes, I had to see a doctor but did not need to go to the hospital), 3 (Yes, I had to visit a hospital as an outpatient), and 4 (Yes, I had to stay in hospital overnight). We used one question to measure bicycle crash involvement: ''In the past 2 years while cycling, have you had an accident whereby your bike was damaged?'' with options 1 (No), 2 (Once), 3 (Twice), and 4 (More often).

*Motorist behaviour rating* was measured using the following question: ''How would you rate the driving behaviour of motorists and van/lorry drivers within the environment you mainly cycle in?'' Response options were provided in the form of a 5-point Likert scale (1 = Excellent to 5 = Very poor).

**Statistical Analysis**

The rate of missing values was low among our analytic sample (1% for any variable). Therefore, we used a list-wise deletion. We used the generalized linear model in IBM SPSS 23 to test the association between study variables and bicycle crash involvement and severity. The generalized linear model was preferred over ordinary linear regression and the general linear model because it allows for outcome variables that have error distribution models different from a normal distribution. Indeed, while ordinary linear regression and the general linear model require that the residuals must follow a conditionally normal distribution, the generalized linear model allows the specification of a non-normal distribution and non-identity-identity link function. We specified a multinomial (ordinal) distribution and a cumulative negative log-log as the link function because the probability of the lower (no crash) category was high. We employed a main-effects-only model with robust covariance matrix estimation. For parameter estimation, we chose a hybrid method in which the use of the Newton–Raphson method is preceded by Fisher scoring iterations.

### 3.2.2. Results

In Study 4, we employed two generalized linear models to investigate the effects of the hypothesized factors and covariates on two outcome variables: bicycle crashes severity (‘‘In the past 2 years whilst cycling, have you had an accident so severe that you had to see a doctor or were taken to a hospital?’’) and bicycle crash involvement (‘‘In the past 2 two years whilst cycling, have you had an accident whereby your bike was damaged?’’).

Table 7 displays the results of a generalized linear model to predict bicycle crash severity. Using the likelihood-ratio chi-square test of the current model versus the null model, we found that the current model out-performed the null model, x2 (30) = 279.01, p .001. The severity of bicycle crashes was positively associated with lower age, not being a student, being employed, using the bicycle for travelling to or from college/ university, not using the bicycle for leisure/training, using an e-bike, lower affective attitudes, higher instrumental attitudes, and the perception of a good motorist driving behaviour. Gender, environment, cycling levels, and bicycle use for commute/travel to or from work taking children to or from school, business trips, shopping/entertainment, personal business, and visiting family/friends were not significantly associated with bicycle crash severity.

Table 7

*Results of the Generalized Linear Model to Predict Bicycle Crash Severity*

| Predictors | B | SE | 95% Wald CI | Wald $x^2$ | p |
|---|---|---|---|---|---|
| Gender | 20.27 | 0.16 | 20.58, 0.04 | 2.99 | 0.084 |
| Age | 20.02 | 0.01 | 20.04, –0.01 | 8.70 | 0.003 |
| *Environment* | | | | | |
| Rural | 20.21 | 0.26 | 20.73, 0.31 | 0.64 | 0.423 |
| Village | 20.13 | 0.24 | 20.60, 0.34 | 0.29 | 0.594 |
| Town | 20.33 | 0.19 | 20.70, 0.03 | 3.18 | 0.075 |
| City (ref.) | | | | | |
| *Working status* | | | | | |
| Retired | 20.20 | 0.40 | 20.99, 0.59 | 0.25 | 0.615 |
| Full-time carer | 20.55 | 1.13 | 22.77, 1.68 | 0.23 | 0.631 |
| Homemaker | 20.37 | 0.44 | 21.24, 0.50 | 0.68 | 0.409 |
| Student | 21.79 | 0.45 | 22.66, –0.91 | 15.99 | 0.000 |
| Not currently working | 20.87 | 0.40 | 21.65, –0.10 | 4.84 | 0.028 |
| Self-employed | 0.17 | 0.25 | 20.32, 0.67 | 0.46 | 0.496 |
| Employed: part time | 0.08 | 0.21 | 20.32, 0.48 | 0.15 | 0.701 |
| Employed: full time (ref.) | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| *Country* | | | | | |
| Sweden | 20.24 | 0.26 | 20.76, 0.27 | 0.85 | 0.357 |
| Italy | 0.29 | 0.24 | 20.19, 0.77 | 1.43 | 0.233 |
| Hungary | 20.55 | 0.31 | 21.17, 0.06 | 3.08 | 0.079 |
| Spain | 0.56 | 0.23 | 0.11, 1.01 | 5.92 | 0.015 |
| Netherlands | 20.21 | 0.26 | 20.72, 0.30 | 0.65 | 0.420 |
| U.K. (ref.) | | | | | |
| Cycling levels | 0.12 | 0.07 | 20.03, 0.27 | 2.65 | 0.103 |
| Commute/travel to or from work | 20.04 | 0.18 | 20.39, 0.31 | 0.05 | 0.829 |
| Travel to or from college/university | 0.63 | 0.22 | 0.20, 1.06 | 8.28 | 0.004 |
| Taking children to or from school | 0.17 | 0.22 | 20.26, 0.59 | 0.60 | 0.439 |
| For business trips | 0.47 | 0.26 | 20.05, 0.99 | 3.17 | 0.075 |
| Shopping/entertainment | 20.05 | 0.16 | 20.37, 0.27 | 0.10 | 0.748 |
| Personal business | 20.07 | 0.18 | 20.43, 0.28 | 0.17 | 0.680 |
| Visiting family/friends | 20.29 | 0.19 | 20.66, 0.08 | 2.29 | 0.130 |
| Leisure/training | 20.48 | 0.16 | 20.80, –0.15 | 8.39 | 0.004 |
| E-bike use | 0.98 | 0.19 | 0.62, 1.35 | 27.85 | 0.000 |
| Affective attitudes | 20.25 | 0.13 | 20.50, 0.00 | 3.94 | 0.047 |
| Instrumental attitudes | 0.40 | 0.13 | 0.14, 0.66 | 9.18 | 0.002 |
| Poor driving behaviour of motorists | 20.35 | 0.08 | 20.50, –0.20 | 19.83 | 0.000 |

*Note*: Gender was coded as male = 1 and female = 2; CI = confidence interval; SE = standard error.

Table 8 shows the results of a generalized linear model to predict bicycle crash involvement. The likelihood-ratio chi-square test revealed that the current model outperformed the null model (x2 (30) = 212.44, p .001). Bicycle crash involvement was positively related to the male gender, lower age, being employed, cycling levels, using the bicycle for travelling to or from college/university, not using the bicycle for leisure/training, and using an e-bike. Environment, affective attitudes, instrumental attitudes, perceived poor driving behaviour of motorists, and bicycle use for taking children to or from school, business trips, shopping/entertainment, personal business, and visiting family/friends were not significantly related to bicycle crash involvement.

Table 8

*Results of the Generalized Linear Model to Predict Bicycle Crash Involvement*

| Predictors | B | SE | 95% Wald CI | Wald $x^2$ | p |
|---|---|---|---|---|---|
| Gender | 20.46 | 0.11 | 20.67, –0.25 | 17.83 | 0.000 |
| Age | 20.03 | 0.01 | 20.04, –0.02 | 23.51 | 0.000 |
| *Environment* | | | | | |
| Rural | 0.16 | 0.17 | 20.17, 0.49 | 0.92 | 0.338 |

| | | | | | |
|---|---|---|---|---|---|
| Village | 20.10 | 0.16 | 20.41, 0.21 | 0.39 | 0.533 |
| Town | 20.12 | 0.13 | 20.37, 0.13 | 0.87 | 0.350 |
| City (ref.) | | | | | |
| *Working status* | | | | | |
| Retired | 20.31 | 0.27 | 20.84, 0.22 | 1.29 | 0.256 |
| Full-time carer | 20.40 | 0.74 | 21.86, 1.06 | 0.29 | 0.589 |
| Homemaker | 20.32 | 0.29 | 20.89, 0.24 | 1.26 | 0.262 |
| Student | 20.22 | 0.19 | 20.60, 0.15 | 1.36 | 0.244 |
| Not currently working | 20.54 | 0.23 | 21.00, –0.08 | 5.32 | 0.021 |
| Self-employed | 20.28 | 0.20 | 20.68, 0.12 | 1.90 | 0.168 |
| Employed: part time | 20.26 | 0.16 | 20.57, 0.06 | 2.51 | 0.113 |
| Employed: full time (ref.) | | | | | |
| *Country* | | | | | |
| Sweden | 20.38 | 0.19 | 20.75, –0.01 | 4.15 | 0.042 |
| Italy | 20.25 | 0.18 | 20.61, 0.11 | 1.88 | 0.170 |
| Hungary | 0.20 | 0.17 | 20.13, 0.53 | 1.40 | 0.237 |
| Spain | 0.44 | 0.16 | 0.12, 0.76 | 7.21 | 0.007 |
| Netherlands | 20.05 | 0.18 | 20.40, 0.30 | 0.08 | 0.779 |
| U.K. (ref.) | | | | | |
| Cycling levels | 0.10 | 0.05 | 0.00, 0.20 | 4.05 | 0.044 |
| Commute/travel to or from work | 0.14 | 0.12 | 20.10, 0.38 | 1.35 | 0.246 |
| Travel to or from college/university | 0.54 | 0.17 | 0.21, 0.88 | 10.15 | 0.001 |
| Taking children to or from school | 0.05 | 0.18 | 20.30, 0.41 | 0.09 | 0.761 |
| For business trips | 0.17 | 0.26 | 20.34, 0.67 | 0.42 | 0.519 |
| Shopping/entertainment | 20.06 | 0.12 | 20.29, 0.18 | 0.22 | 0.638 |
| Personal business | 0.06 | 0.13 | 20.20, 0.32 | 0.21 | 0.647 |
| Visiting family/friends | 0.00 | 0.13 | 20.26, 0.25 | 0.00 | 0.983 |
| Leisure/training | 20.25 | 0.11 | 20.48, –0.03 | 4.93 | 0.026 |
| E-bike use | 0.66 | 0.15 | 0.37, 0.96 | 19.34 | 0.000 |
| Affective attitudes | 0.06 | 0.08 | 20.11, 0.22 | 0.50 | 0.479 |
| Instrumental attitudes | 0.03 | 0.08 | 20.13, 0.20 | 0.16 | 0.689 |
| Poor driving behavior of motorists | 20.02 | 0.05 | 20.13, 0.08 | 0.16 | 0.687 |

*Note*: Gender was coded as male = 1 and female = 2; CI = confidence interval; SE = standard error.

### 3.2.3. Discussion

The aim of Study 4 was to test the association between attitudes towards cycling, e-bike use, cyclists' perception of driving behaviour of motorists, and the likelihood of bicycle crash involvement and severity. To this end, we involved a large sample of European regular-cyclists. The results from this study provided support for our four hypotheses, at least for one of the two outcomes (i.e., bicycle crash involvement and severity).

The most important factor associated with both bicycle crash involvement and severity was e-bike use (Hypothesis 4). This is an important finding that reinforces the preliminary evidence of greater crash risk among e-bike users than classic-bicycle users (Fishman & Cherry, 2016). Cyclists' and motorists' behaviours are common causes of bicycle crashes (Prati et al., 2018). It seems likely that the behaviours of e-bike users may change in a way that increases their crash likelihood. One reason may be speed. Low cycling speeds may protect against cyclists' crash involvement. For instance, compared with those reporting lower speeds, cyclists reporting speeds above 25 km/h before their crash were more likely to report severe injury (Schepers, Fishman, Den Hertog et al., 2014). In addition, motorists tend to accept unsafe gaps (e.g., for turning manoeuvres) when the approaching bicycle is faster (Petzoldt et al., 2017a; 2017b). There is evidence that e-bike users reach higher speeds than classic-bicycle users (Schleinitz et al., 2017; Langford et al., 2015; Lin et al., 2008; Dozza et al., 2016). Moreover, e-bike users tend to cycle significantly faster than classic-bicycle users immediately before a traffic conflict (Petzold et al., 2017b), suggesting their speed was a contributing factor to the event. Furthermore, motorists may also underestimate the speed at which e-bikes approach, probably because e-bikes are visually indistinguishable from classic bicycles. There is evidence that motorists tend to accept shorter (i.e., unsafe) time gaps for crossing in front of an approaching e-bike compared with a classic bicycle riding at the same speed (Petzold et al., 2017a). Furthermore, e-bike users perceive that other road users are not expecting them to approach as rapidly as they do, thereby not respecting the right of way of the cyclists (Popovich et al., 2014). Based on the results of the present study, we can rule out the possibility that the difference between e-bike users and classic-bicycle users are the result of relevant sociodemographic differences. For example, the e-bike user population may be skewed toward older riders, and age may be related to crash severity (Prati, Pietrantoni & Fraboni, 2017). Since we controlled for age in our analysis, the higher likelihood of bicycle crash severity among e-bike users compared with classic-bicycle users cannot be the result of differences in age.

Consistent with Hypotheses 1 and 2, we found that cyclists scoring high on affective attitudes and low on instrumental attitudes were less likely to report severe bicycle crashes. To our knowledge,

this is the first study investigating the relationship between instrumental and affective cycling journey attitudes and bicycle crash severity. We posit that instrumental attitudes are associated with bicycle crash severity because cyclists may view traffic situations as more controllable and predictable, thereby underestimating the risks of dangerous interactions with motorized vehicles. Conversely, affective attitudes are related to the avoidance of such dangerous traffic situations because they are unpleasant and perceived as unsafe. These explanations need to be tested in future studies. However, we note that instrumental and affective cycling journey attitudes were not associated with bicycle crash involvement. Collisions between cyclists and motorized vehicles are more likely to cause serious injuries (Chong et al., 2010; Nicaj et al., 2009; Rosenkranz & Sheridan, 2003; Sze et al., 2011; Rowe et al., 1995) than single-bicycle crashes (i.e., non-collision accidents or collisions with fixed and stationary objects), which constitute the large majority of crashes. Our interpretation is that affective attitudes are less related to collisions with motorized vehicles (i.e., resulting in more severe crashes) than instrumental attitudes. Future research is needed to address this explanation.

Another novelty of the present work was the finding that the more the driving behaviour of motorists and van/ lorry drivers was rated as poor, the lower the likelihood of having a severe crash (Hypothesis 3). This finding may indicate that risk perception in relation to a cyclist– motorist interactions may lead to the avoidance of cycling in mixed traffic (Prati et al. 2018a, O'Connor & Brown, 2010; Chataway eta al., 2016), thereby reducing the risk of having severe crashes. This cyclists' self-exclusion from cycling on the road with the general traffic is consistent with the notion of cyclists as minority road users (Prati et al., 2017).

Another important finding of the present study is that as age increased, the likelihood of bicycle crash involvement and severity decreased. This finding could be explained by the inexperience of young cyclists as road users (Twisk & Stacey, 2007), the age differential in risk-taking behaviour (Turner & McClure, 2003), and other developmental sources of crash risk in young drivers such as peer pressure, and adolescent emotionality (Arnett, 2002). In addition, the avoidance of cycling in mixed traffic is positively related to age (Chataway et al., 2014).

Consistent with results from Study 2 and with previous studies (Yan et al., 2011; Tin et al., 2010; Prati, De Angelis, Marìn Puchades et al., 2017), we found that male cyclists are more likely to be involved in crashes than female cyclists, even after controlling for cycling levels and other covariates. This is in good agreement with the notion that male cyclists are more likely to commit violations (e.g., excessive speeding, not yielding the right of way) than female cyclists (Yan et al., 2011; Johnson et al., 2016; Bernhoft & Carstensen, 2008; Deffenbacher, 2008). Gender differences in the likelihood of suffering a severe injury showed a tendency to significance. In Study 3 we found

gender differences in the severity of bicycle crashes were significant only on urban municipal roads, while there was no evidence of gender differences on the other types of road.

In the present study, we also evaluated factors not directly related to our hypotheses, such as cycling purposes, which were included as controlling variables. Cycling to or from college/university can be considered a form of commuting cycling (Molina-García et al., 2010), thus supposing the use of the bicycle mostly during peak hours (i.e., the most dangerous period) in which bicycle crashes and involvement are more likely (de Geus et al., 2012; Kim et al., 2007). Employed people, as well as students, may be more likely to be making commuting trips, which are high frequency and undertaken when a lot of vehicles are on the roads. Conversely, cycling for leisure/training was negatively associated with being involved in a bicycle crash or incurring a severe crash. It could be argued that cyclists in this cohort are more proficient at and aware of the strategies, gained through experience, for minimizing the impact of traffic (O'Connor & Brown, 2010). Future studies are needed to understand the mechanisms underlying these relationships.

Some limitations of the study should be considered. The major limitation was the reliance on cross-sectional self-report data, which precludes us from making strong causal statements about our results. In addition, social desirability and recall bias may have affected the results. In the present study, e-bike users were defined as those who ride an electric bike most frequently; however, we cannot exclude the possibility that they occasionally use classic bicycles as well. Finally, the study population was self-selective (i.e., an online panel). Therefore, the generalizability of the findings is limited. Notwithstanding this, the sample was large and included several countries and different types of cyclists. Bicycle riders' behaviour, road type, and cycling infrastructure were not considered in the present study. Future research may examine whether the effects of journey attitudes, e-bike use, and perception of driving behaviour of motorists on bicycle crash involvement and severity differ across road type or cycling infrastructure, and which aspects of bicycle riders' behaviour might explain such effects.

# Chapter 3

## 4. General discussion

The present thesis focuses on cycling as a mean of transportation and, on the one hand, it aims to contribute to expanding the knowledge about psychosocial factors related to bicycle use and cycling patterns in Europe. On the other hand, it seeks to assess if and how psychosocial factors such as gender, culture and attitudes can influence safety outcomes in traffic. A specific focus on gender-related differences is posed both in the topic of bicycle use and cycling safety. The theoretical and practical implication of the present work will be discussed in the following chapter.

### 4.1. Theoretical implication

This research has made a substantial contribution to unravel common patterns, attitudes, and psychosocial characteristics of groups of cyclists in Europe, which is one of the less investigated aspects if compared to other modes of transport. Considering the comprehensive cross-national European sample, much of the research presented in this work can apply to most of the countries belonging to the EU area, whether they are from southern Europe, central Europe or northern Europe. However, the large discrepancies in European countries' cycling cultures should imply caution when using the presented typologies of cyclists as guidance for developing policies and interventions. In general, the relationship between provision and quality of infrastructure and the probability of belonging to the Resolute Cyclist suggests that every intervention that aims at increasing the use of the bicycle in a specific area could not refrain from addressing the built environment. On that matter, our study suggests how different attitudes can be leveraged to tailor behaviour change interventions and build upon existing initiatives, maximising their impact on changing the behaviour of citizen and increasing the levels of bicycle use, with particular attention to curb gender-related inequalities in bicycle use.

Furthermore, findings from Study 2 propose that, when considering regular cyclists, gender-related differences in attitudes towards cycling tend to fade. This highlights a bidirectional causal relationship regarding attitudes towards cycling and cycling behaviour. Indeed, women are less likely to use bicycles than men because they have different attitudes towards cycling. Still, women also exhibit different attitudes towards cycling because they are less likely to use bicycles. Such a result is following the assumptions of self-perception theory (Bem, 1967), which states that people tend to use their behaviour as a source of evidence for their beliefs and attitudes. Still, it is essential to highlight that evidence suggests the existence of a two-way relationship between behaviours and

attitudes. Results from Study 2 also show support for the fact that male cyclists report lower risk perception of cycling but, at the same time, they have a higher likelihood of suffering a bicycle crash when compared to female cyclists.

Study 3 further contributed to the matter, showing that, even if the effect size of the relationship was medium, male cyclists report a higher risk of suffering a fatal injury when compared to female cyclists. Moreover, crash characteristics have been found to be different for male and female cyclists, with a small but statistically significant the effect size. According to previous evidence, we argued that such differences could find a possible explanation in socio-cultural factors, such as cycling culture and hegemonic masculinity, as well as psychological factors, such as gender differences in road safety attitudes and risk perception. To what regards gender differences in risk perception and the probability of being involved in cycling crashes, alongside the notion of hegemonic masculinity, it is possible to discuss our results further. Previous authors argued that the traditional ideal of masculine strength prompts men who adhere to it to perceive prevention as unnecessary and worrying about the possible consequences of risky activities as de-virilizing. Specifically, Mahalik, Burns and Syzdek (2007) showed that masculinity and the perceived normativeness of other men's health behaviours significantly predicted participants' health behaviours, controlling for sociodemographic variables (e.g., education, income). According to their results, the authors argued that men tend to disregards risks, putting their health in danger due to traditional masculine gender socialization and social norms models. In the traditional idea of masculinity, a real man is strong, his body is invulnerable to illness, and showing that he is reckless can be a signal of masculinity. Available research indicates that men who adhere more closely to dominant norms of masculinity are also those who engage in more frequently engage in unhealthy behaviours. Dominant norms of masculinity could prompt males to engage in behaviours that are risky for themselves and could also be dangerous for others. In the context of cycling, Balkmar (2018) showed that male motorised vehicles drivers tend to enact gender-identity-shaping practices towards cyclists and that this contributes to spreading inequalities and vulnerabilities for cyclists in car-dominated space. The author concluded that shifts in masculinities and men's practices in transport and traffic are much needed for promoting a shift from cars to bicycles. Future studies could also examine if and how adherence to traditional patterns of masculinity impacts the likelihood of bicycle crashes or risk perception perceptions.

Study 4 provided additional evidence on factors contributing to cycling crashes and injuries, explicitly identifying male cyclists as more likely to be involved in crashes than female cyclists even after controlling for cycling levels and other covariates. We also found e-bike use to be a significant

factor associated with both bicycle crash involvement and severity. This finding is of particular importance and supports preliminary evidence suggesting greater crash risks for e-bike users (Fishman & Cherry, 2016). We argued that explanations for this increased risk should reside in e-cyclists and motor vehicle drivers' behaviour (e.g. speeding, safe gap tolerance and intersection approaching behaviour). We also were able to dismiss the argument that the differences mentioned above in crash involvement risk are related to sociodemographic differences. Another meaningful finding of Study 4 is that cyclists scoring high on affective attitudes and low on instrumental attitudes were less likely to report severe bicycle crashes. It is the first time that a study can document evidence of e relationship between instrumental and affective cycling journey attitudes and bicycle crash severity. Theoretically, we explained such results considering that affective attitudes are linked to avoidance of mixed traffic, while instrumental attitudes are more related to overconfidence. Future studies should attempt at shedding light on this relationship. This is as well backed by to another novel result of study 4, that is, the more a cyclist assesses driver behaviour as unfavourable, the less likely he/she is to have a severe accident. This finding may support the idea that risk perception concerning cyclist–motorist interactions may lead to the avoidance of cycling in mixed traffic (Prati et al 2018a, O'Connor & Brown, 2010; Chataway eta al., 2016), thereby reducing the risk of incurring in severe crashes. The conceptualization of cyclists as minority road users (Prati et al., 2017) finds additional support in this self-exclusion behaviour of cyclists. As we also found a significant effect for age about cycling crashes involvement and severity. While seemingly counter-intuitive and partially in contrast with previous studies, that found elderly cyclists to be at greater risk, it is possible to find reasonable explanations. The inexperience of young cyclists as road users (Twisk & Stacey, 2007), the age differential in risk-taking behaviour (Turner & McClure, 2003), and other developmental sources of crash risk in young drivers such as peer pressure, and adolescent emotionality (Arnett, 2002) are possible causes.

In conclusion, we would like to stress that bicycles still need to be acknowledged and accepted as a legitimate mode of transport on a deeper social level, not only in policy and strategic documents. In order to develop a safer cycling environment for the population, there is a need to promote greater integration and acknowledgement of cyclists as road users.

### 4.2. Practical implications

The practical implications of our study are multifaceted and can provide valuable insights at different levels, such as social, political, and institutional. Study 1 provided useful knowledge that can be used by experts to hone the European Cycling Strategy (ECF, 2017) as well as sharpening policies and behaviour change intervention to increase the share of bicycle use. It is in fact reasonable

to argue that each of the three typologies of cyclists we identified could be differently responsive to campaign and interventions leveraging on a different type of messages and actions, in accordance with specific attitudes they hold and purpose for cycling. Again, the role of culture and cycling infrastructure has been mentioned as primary in determining cycling levels and behaviours. As it was suggested by other authors (Sweiers et al., 2017) common interventions aimed to increase cycling use, have focused mostly on reducing barriers to cycling, thus predominantly addressing cycling safety, often neglecting motivators. As it has been already advocated by previous authors, actions aiming to increase cycling share should embrace an ecological approach addressing primary barriers (safety, infrastructures) as well as primary motivators (fitness, weight management) in order to maximise effectiveness and, at the same time, remaining aware of variations in barriers and motivators between regular and non-regular cyclists and male and female cyclists (Sweiers et al., 2017). Findings of the present thesis pinpoint useful information that should be used to develop comprehensive strategies for increasing cycling levels.

Findings from Study 2 provide some insights for interventions aimed at promoting cycling and increasing cycling behaviours specifically among women. For instance, instead of focusing only on the promotion of positive attitudes towards cycling, interventions should promote increasing cycling behaviours through organising social events and opportunities for cycling to demonstrate the positive aspects of cycling (e.g. the personal benefits of cycling). The results indicate that women experience higher discomfort in mixed traffic, thus suggesting that, when traffic-calming measures are not feasible, provision of segregated cycling infrastructure (e.g. cycling paths) should be improved to increase the comfort of female cyclists. We argue that the development of bicycle paths separated from the rest of the traffic or traffic calming measures (e.g. speed bumps, 30km/h limit areas) can foster higher gender balance in bicycle use. Furthermore, to ensure gender balance in bicycle use, we advocate that women should have a stronger participation in providing input for transport infrastructure design and urban planning. Findings of Study 2 about male cyclists' crash involvement rates and risk perception emphasize the importance of devising ways to increase risk perception among this group of cyclists. Social marketing efforts represent a feasible and effective means to promote gender equality in cycling (e.g. focusing on challenging traditional gender roles) and also to bolster safety and injury prevention for male cyclists.

According to Study 3 results, it was possible to pinpoint differences between male and female cyclists' errors and risky behaviours. This should be addressed in cycling education and training programs as well as in public awareness initiatives. More in general, any type of intervention should be sensitive to such gender differences. Road safety education should particularly take into account

beliefs bound to cultural constructions of masculinity and femininity (Walker et al., 2000). Advertisement based awareness campaign targeting road safety and personal health should evaluate how different type of messages are differently effective for men and women (Lewis et al., 2007; Ulleberg, 2001). In particular for cycling safety, interventions should be developed coherently to gender-related crash patterns (e.g. rural road vs urban road; speeding, or crossroad crashes). This information is likely to provide important guidance in the design and implementation of road safety advertisements and personal health campaigns. Adding on findings of Study 2, results of Study 3 also bring up new issues about the priorities of transport decisions makers when investing in cycling infrastructure. Those bicycle infrastructures minimizing the interaction with motorized vehicles should be prioritised as they could be beneficial in particular for the safety of female cyclists.

Study 4 further provides important insights with regard to the association between instrumental and affective cycling journey attitudes, perceptions of the driving behaviour of motorists, use of an e-bike, age, gender, and the likelihood of bicycle crashes. These factors should be carefully considered by programs that aim to prevent bicycle crashes. Results from Study 4 stress the importance of paying particular attention to e-cyclists behaviour. Further studies are needed to address the issue. Nevertheless, preliminary results clearly highlight an increased risk for this particular segment of cyclists. We suggest that designers and engineers should leverage recent technological advancements to increase e-cyclists safety through the implementation of innovative safety technologies on bikes. From a policy perspective, the implication is that cyclists' perceptions of the driving behaviour of motorists should be taken into account when designing bicycle master plans. In addition, social marketing campaigns are needed to raise awareness of the rights of cyclists on the road and acceptable road behaviour among motorists and cyclists. Finally, the use of bicycle warning signs may help to promote positive changes in driver behaviour (Kay et al., 2014). Road signs should be clear, simple, unambiguous, and precise: For instance, a ''Bicycles May Use Full Lane'' sign combined with shared lane markings was found to increase awareness of the roadway rights and responsibilities of bicyclists and motorists, ideally promoting safety (Hess & Peterson, 2015). Study results also indicate that clear bicycle warning signs, social marketing campaigns, and road safety education programs for motorists, and male and young cyclists, as well as e-bike users, are needed to foster cyclists' safety and, ultimately, promote the large scale adoption of cycling for utilitarian and recreational purposes.

Results on gender differences in cycling crashes, taken together, suggest the need to develop and implement effective road safety education programs for male cyclists and young cyclists. There

is evidence that road safety education programs may be useful in improving safety behaviour (Twisk et al., 2014).

Lastly, following the work from Sleet et al. (2011), we would like to stress that joint actions of researchers, professionals, policymakers and citizens' representative should focus on strengthening initiatives that are necessary to achieve the objective posed by road safety Vision-zero strategy (Johansson, 2009). Topics that are related to the current thesis, but not here directly address includes:

- Ways of incorporating traffic safety culture into education programs for the youthful, helping in safety behaviours and habit formation of youngsters;
- Reducing inequalities related to traffic safety by guaranteeing access to safety devices such as kid security seats, bicycle light and helmets, as well as not leaving out disadvantaged neighbourhoods from safety initiatives;
- Incorporating safety and active mobility into healthy ageing programs;
- Implementing measures for continuous monitoring of cycling-related injuries costs both in terms of physical and mental health.

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