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Abstract

Cyclists’ crashes account for a relatively large proportion of road fatalities and this proportion is increasing. Research suggests that near misses can be used as surrogate measures of crashes, based on the assumption that they share common causes. Also, in the cycling domain, it has been suggested that near miss incidents may provide ‘early warnings’ of situations or behaviours that could lead to crashes. The aim of this study was to investigate the role played by perception of risk and control on the exposure to risky situations, such as the involvement in mixed traffic. We administered a questionnaire to 298 Italian cyclists measuring perceived competence (i.e. perceived control and overconfidence), risk perception of interactions with cars, bicycle use, avoidance of mixed traffic and recent experiences of near misses. Path analysis using Bayesian estimation showed that perceived control, mediated by overconfidence, had a positive indirect effect on bicycle use and a negative one on avoidance of mixed traffic, while it acted as a moderator in the relationship between risk perception of interaction with cars and avoidance of mixed traffic. Furthermore, the mediation paths revealed the indirect effects of perceived control on near misses through exposure. Results highlighted the importance of considering the role of individuals’ perception of their ability to cycle with regard to near misses and provided new insight on how cyclists regulate their behaviour, as well as how such behaviour leads to different safety outcomes. Results have implications regarding theory, infrastructure and the application of new safety technologies.

Key terms: *Risk Perception, Overconfidence, Perceived Control, Near Miss*.

1. Introduction

Risk perception has been found to reduce risky behaviours and the probability of safety outcomes by behavioural adaptation both theoretically and empirically (Ba et al., 2016; Koornstra, 2009). Moreover, perceived competence, in the meaning of the perceived capabilities that one possesses over one task, has been also proposed to be part of the behavioural adaptation process influencing the level of difficulty associated with a task (Rudin-Brown & Jamson, 2013). Both risk perception and perceived competence are cognitive constructs of utmost importance when modelling road users' behaviour due to their relationship with behavioural adaptation, nevertheless, there is lack of research addressing their influence on cyclists' safety outcomes (i.e. near misses). Thus, the present study aims to shed light on the interactions between perceived competence and risk perception and their effect on cyclists' involvement in risky situations and safety outcomes in cycling.

1.1. Crashes and Near Misses among Cyclists

In the last decade, the amount of research investigating cycling safety has dramatically increased (e.g. Heydari, Fu, Miranda-Moreno, & Joseph, 2017; Jacobsen, Ragland, & Komanoff, 2015; Osama & Sayed, 2016; Prati, Marín Puchades, De Angelis, Fraboni, & Pietrantoni, 2017). Several reasons might be the source of such interest. First, even though cyclists represent a small minority in comparison with motorised vehicles (Prati, Marín Puchades, & Pietrantoni, 2017), they account for a relatively large proportion of fatalities (ERSO, 2016). In fact, in 2014 there were 2112 cyclists' fatalities in the EU countries, which correspond to the 8.1% of all the road deaths (ERSO, 2016) showing an increase of 0.3% compared to 2013. In addition to this, infrastructure is usually not designed to provide cyclists with safety conditions comparable to other road users (e.g. car drivers), therefore, their level of protection is considerably lower (Wegman et al., 2012).

Fatality trends and other safety outcomes (e.g. the number of non-fatal crashes) vary along different EU countries. In Italy, according to the Italian National Institute of Statistics (ACI-ISTAT, 2015), on a total of 17437 crashes involving at least one cyclist in 2015, 16827 cyclists were injured and 252 died within 30 days following the crash. These data show a decrease of 3.2% in the injuries and of 7.7% in the fatalities compared to the previous year. In Italy, the mortality index (deaths every 100 accidents) for cyclists is 1.44, which is higher in comparison with the mortality index of car users (0.88).

In the safety domain, using Heinrich's Safety Triangle model, accidents are on the pinnacle of the pyramid, whereas near misses are found below them being more frequent and less severe (e.g. Hamann & Peek-Asa, 2017; Heinrich, 1950). A near miss can be defined as an event that did not cause any harm and therefore has limited immediate impact. Near misses have been used as surrogate measures of crashes since they both have been found to share common causation (Wright & Van der Schaaf, 2004). Moreover, safety outcomes with lower severity (i.e. near misses) are more frequent, thus, more susceptible of being studied (Laureshyn, de Goede, Saunier, & Fyhri, 2017). At a theoretical level, Güttinger (1982) proposed a model in which a conflict is defined as a set of initial conditions that, depending on the successfulness of the evasive action, either develop further into a collision or resolve without any consequences. This definition implies the existence of a continuum in which conflicts always precede crashes and with the possibility for the conflicts to develop either in a crash or in an avoided crash – near miss. In other words, this model can be interpreted in a way that a conflict is a set of circumstances that either results in a crash or not.

In the cycling domain, the relationship between near misses and crashes is yet to be understood. In accordance with Güttinger's (1982) model, Aldred (2016) suggests that near miss incidents may provide 'early warnings' of situations or behaviour that could lead to crashes. Moreover, Aldred (2016) compared percentages of attribution of near misses and crashes in the study of Knowles' et al. (2009) and found that they were very similar, giving support to the shared causation.

Despite these early studies, cycling near misses remain under-researched, regardless of their likely contribution to injury crashes (Aldred, 2016). Nevertheless, more and more innovative solutions and methodologies attempted to address such matter (i.e. Aldred & Crosweller, 2015; Westerhuis & De Waard, 2016). Some studies, such as Aldred and Crosweller (2015), and Joshi, Senior, and Smith (2001) in the UK, and Sanders (2015) in the San Francisco Bay Area, have also shown that near misses are a very common experience for cyclists. For example, using an online diary methodology, Aldred and Crosweller (2015) found that the 75% of participants experienced at least .75 incidents per cycled hour, with a median of 1.71 per hour. Similarly, using a self-reported questionnaire, Sanders (2015) showed that 86% of those who bicycle at least annually in this sample had experienced some type of near miss.

1.2. Cycling Levels and Avoidance of Mixed Traffic as Exposure

Exposure is of utmost importance when it comes to studying cycling safety. Research suggests that studies that intend to estimate the importance of factors other than exposure in crashes and injuries must control for exposure given to its overall effect on cycling safety and risk of crash and injury (Vanparijs et al., 2015). Moreover, its effect on crash and injury risk has been consolidated over the years by research (Carlin et al., 1995; Bacchieri et al., 2010).

In the present study, we consider exposure at two different levels: (1) exposure to cycling in general, that is to say, use of the bicycle; and (2) cycling in mixed traffic situations. The latter type of exposure allows for more opportunities for cyclists to interact with cars, which is of especial importance when considering risk. Evidence shows countries and cities with extensive bicycling facilities have the highest cycling modal split shares and the lowest fatality rates (Pucher, 2001; Pucher & Dijkstra, 2000). Those countries and cities without separate facilities have low modal split shares and much higher fatality rates (Buehler & Dill, 2016; Pucher & Dijkstra, 2000). However, in emerging cycling regions where cyclists are rapidly growing in number, cyclists are forced to share the road with motorised vehicles due to the underdevelopment of cycling infrastructure (e.g. Pucher et al., 2011). Cyclists in urban area may have to choose between (1) cycle within mixed traffic situations with shorter travel time, (2) cycle on bike lanes or segregated paths with a longer travel time, and (3) use other means of transport. The two latter options would imply avoiding mixed traffic and, therefore, the risk of conflicts with road users in it.

For this reason, in our model (fig. 1) we hypothesise that, on the one hand, avoidance of cycling in mixed traffic will be negatively associated with the occurrence of near misses (Hypothesis 1). In other words, the more cyclists avoid mixed traffic situations, the lower the probability of being involved in a conflict (i.e. near miss), especially with vehicles generally involved in mixed traffic. On the other hand, concerning exposure to cycling in general and according to the aforementioned, we hypothesise a positive association between bicycle use and near misses (Hypothesis 2).

1.3. Risk Perception of Interaction with Cars

Risk-adaptation theory proposes that road traffic risk perception depends on fear and arousal (Koornstra, 2009). Cyclists feel most secure on road with cycle tracks and most at risk on roads with mixed traffic, while cycle lanes can be considered half way: less secure than cycle tracks, but considerably more secure than mixed traffic roads (Jensen et al., 2007). In particular, it has been shown that the presence and the size of motor vehicles (Aldred, 2016) increase cyclists' feeling of being at risk. Moreover, previous experiences set up the adaptation level around which there is a range of indifference to risks (Koornstra, 2009). Such level and ranges vary between individuals; therefore, one can also expect variance in the degree of risk which cyclists incur depending on their own personal characteristics, leading to potential compensations (Koornstra, 2009; Wilde, 1982) in terms of strategic decisions (e.g. taking the bicycle over other means of transport, choosing one path to work instead of another) or driving behaviours (e.g. riding at a certain speed, committing violations or not, keeping safe or unsafe distance from other road users). This way, avoiding mixed traffic can be a strategy to cope with perceived risk (Chataway et al., 2014; Kaplan & Prato, 2016; O'Connor & Brown, 2010) which, as other forms of behavioural adaptation, might lead to a decrease of the objective probability of crash or events with potential hazards (Ba et al., 2016). Therefore, we hypothesised that risk perception regarding interaction with motorised vehicles will be positively associated with avoidance of mixed traffic (Hypothesis 3). In other words, the higher the perception of risk in interactions with motorised vehicles, the more cyclists will avoid mixed traffic situations.

1.4. Perceived Competence

Perceived competence in riding a bicycle can be considered as a form of control over one's riding (Chaurand & Delhomme, 2013). Cristea and Gheorghiu (2016) found that perceived behavioural control over certain situation was a good predictor of the behavioural intention to take part in such situations. Perceived behavioural control refers to the individual's perception of his or her ability to execute a given behaviour (Ajzen, 1991). According to this, people will likely choose to perform behaviours they think they will be capable of executing. The concept of perceived behavioural control is very similar to that of self-efficacy (Bandura, 1982) and it captures people's perceived capability to execute a given behaviour, for example, travelling to work by bicycle (Lois et al., 2015). With that said, perceived control can be defined as a self-perception regarding the own capabilities and ability to control one's own action to execute a given behaviour, in other words, how skilled and effective people perceive themselves to be given particular conditions. According to this framework it is reasonable to argue that perceived control will influence how much a person will engage in a certain behaviour. In the context of the present study, we hypothesise that increasing levels of perceived control will be positively associated with weekly rates of bicycle use (Hypothesis 4).

Previous studies have found that the perceived control over a driving situation predicts the disposition to take higher levels of risk (Horswill & McKenna, 1999). Moreover, people tend to better accept controllable rather than uncontrollable risks (Nordgren et al., 2007). Furthermore, in driving safety research, a reduced risk avoidance in road traffic has been found when drivers' perception of control is higher (Horswill & McKenna 1999; Windsor et al., 2008). Considering the inherent risk of involvement in mixed traffic and the decision to avoid mixed traffic situations as a coping strategy to reduce the perceived risk (Chataway et al., 2014; Kaplan & Prato, 2016; O'Connor & Brown, 2010), higher perceptions of control may influence cyclist's behavioural intention to ride in a stressful traffic environment such as mixed traffic scenario (Kaplan & Prato, 2016; O'Connor & Brown, 2010). Therefore, we hypothesised that perceived control will be negatively associated with avoidance of mixed traffic (Hypothesis 5). In other words, the higher the perception of control, the more cyclists will be involved in mixed traffic, since they will avoid less.

Perceived control may be seen as a positive trait since it is associated with self-efficacy and performance therefore (Wohleber & Matthews, 2016). Nevertheless, Weinstein (1980) found that when thinking about future events, situations that were perceived as controllable led to motivational and cognitive factors that tended to increase the perceived likelihood that the given situation would unfold the way the person wanted, therefore, it would lead to unrealistic optimism (Weinstein, 1980). When such perception of control exceeds the real control a person has over the bicycle, it can be labelled overconfidence (Wohleber & Matthews, 2016). Thus, perception of control leading to unreasonable optimism can generate overconfidence regarding the future being linked to your control, in other words, to your skills and capability to control the situation and outcomes. Therefore, we hypothesised that perceived control will lead to overconfidence in the person's skills because of unrealistic optimism (Hypothesis 6).

Moreover, in driving safety research, overconfidence has been found to be related to riskier behaviours among drivers (Hatfield & Fernandes, 2009; Wohleber & Matthews, 2016). Chaurand and Delhomme (2013) found that higher levels of overconfidence in one's cycling skills were associated with lower risk perception. Thus, cyclists with higher overestimation of their own skills might see dangerous or hazardous situations, such as committing a violation, as relatively less risky. In addition, they will feel more capable to deal with them or to handle the potential consequences of external sources of risk, such as interaction with other road users. Therefore, perceiving oneself as more competent than one actually is, may lead to not avoiding situations that, otherwise, would be considered hazardous. Thus, we hypothesise that increasing levels of overconfidence will be associated with lower avoidance of mixed traffic (Hypothesis 7) as well as with a higher rate of bicycle use (Hypothesis 8). Based on the reasoning presented for hypothesis 6, we established that the relationship between perceived control and bicycle use is indirectly explained through overconfidence (Hypothesis 9) as it is the relationship between perceived control and avoidance of mixed traffic (Hypothesis 10). Finally, in order to further understand the relations between our variables, we expect to find an indirect effect of multiple mediators on the relationship between perceived control and near misses throughout the influence of overconfidence which in turn, will have an effect on near misses through the parallel mediators bicycle use and avoidance of mixed traffic (Hypothesis 11).

Research addressing perceived control and risk perception has mainly focused on their relationship, raising the need for investigating the possible effect of the latter on risk acceptance. Cordellieri's, et al., (2016) findings suggested that worrying about the risk might influence the reduction of hazardous behaviours. Based on the assumption that trusting one's skills leads to unrealistic optimism (Weinstein, 1980), we propose that for people with high control over one's own skills, there will be less worry about the risk even if the hazard is perceived equally risky. Thus, cyclists with higher levels of perceived control might base their decision to take part in the risky behaviour mainly for reasons other than the level of risk, because they might be less worried about such a risk. Therefore, we propose that, while risk perception might be a predictor of acceptance of the risk (i.e. interaction with mixed traffic), perceived control could play a relevant role in shaping the context in which risk perception is considered to be important when deciding to take such risk. That is, we hypothesise that with high levels of perceived control, risk perception will not play an important role in the prediction of acceptance of the risk, whereas, with lower levels of perceived control, the decision to engage in the risky behaviour will be made on the basis of risk perception. In other words, we hypothesise that the relationship between risk perception and avoidance of mixed traffic will be moderated by perception of control (Hypothesis 12).

Figure 1 displays the hypothesised path model.

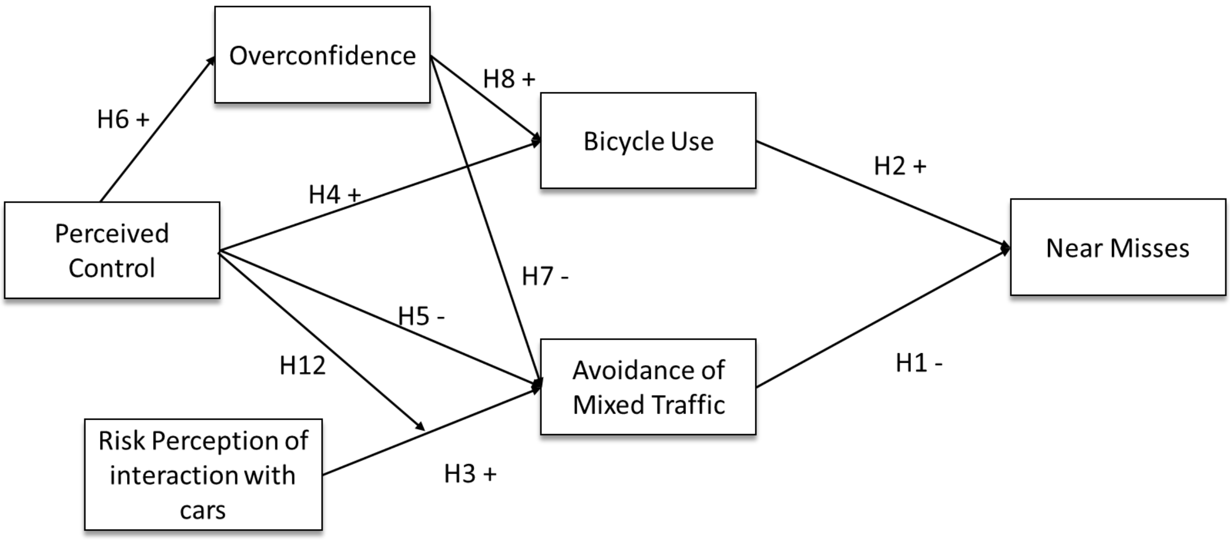

Figure 1. Hypothesised Path Model. The characters next to each arrow point out the hypothesis and the sign of the expected association. Hypotheses 9 to 11 are not included since they foresaw mediation (i.e. involving more than one arrow).

2. Method

2.1. Procedure

Data were collected from December 10, 2015 to February 29, 2016 through an online questionnaire in Italian. To attempt to reduce the self-selection bias and to reach a wide variety of participants, we included groups targeting cyclists with all sorts of demographic characteristics and from different locations in Italy. Cyclists associations' websites, Facebook groups, and forums were found using keywords (i.e. the Italian words for "cycling" "bicycle" "cyclists' association") on Google and on Facebook's search engine. Facebook groups with less than 500 participants were discarded. We contacted in total 45 Facebook groups and 29 websites. In order to reach the selected targets two methods were used: (a) firstly, the link to the questionnaire was directly posted on Facebook groups' walls or on websites bulletin boards if available; (b) secondly, an email was written to the website administrators, asking to kindly advertise the questionnaire directly on their website, through their social media channels or inside their newsletter. Participants were offered no reward for participation.

Italy is a country with certain regions that have growing cycling levels but that still lacks infrastructure devoted to cyclists in comparison with other European countries with longer cycling traditions. Therefore, it is likely that many people may be forced to choose between getting involved in mixed traffic or using other means of transportation.

2.2. Participants

A total of 455 participants answered the questionnaire. After considering only those participants who had filled out the items for age, sex and that acknowledged to use the bicycle at least once a week, the remaining sample comprised 298 (65.5%) participants. From these, 178 (59.7%) were male, 119 (39.3%) were female and 3 (1.0%) did not identify with male-female categories. The age of the participants ranged from 19 to 72 years. The mean for females was 37.1 (*SD* = 14.4), the mean for males was 45.8 (*SD* = 13.9), whereas the general mean was

42.5 (SD = 14.7). Moreover, 189 (63.4%) participants were employed, 70 (23.5%) were students, 10 (3.4%) were unemployed, and 29 (9.7%) were retired. Regarding their educational background, more than half of the sample had a Bachelors' or Masters' degree (166, 52.4%), 83 (27.8%) had high-school or middle school education and the rest (i.e. 59, 19.8%) had PhD-level studies.

Figure 2 displays the percentages of weekly bicycle use. Moreover, regarding the frequency of use in comparison with other means of transportation, 28.2% of the participants reported using the bicycle as a primary mode of transportation. Finally, 119 (39.9%) participants had not suffered any bicycle crash, 117 (39.3%) participants suffered at least one crash but did not get injured, whereas 60 (20.1%) of them had been involved in a bicycle crash in which they got injured.

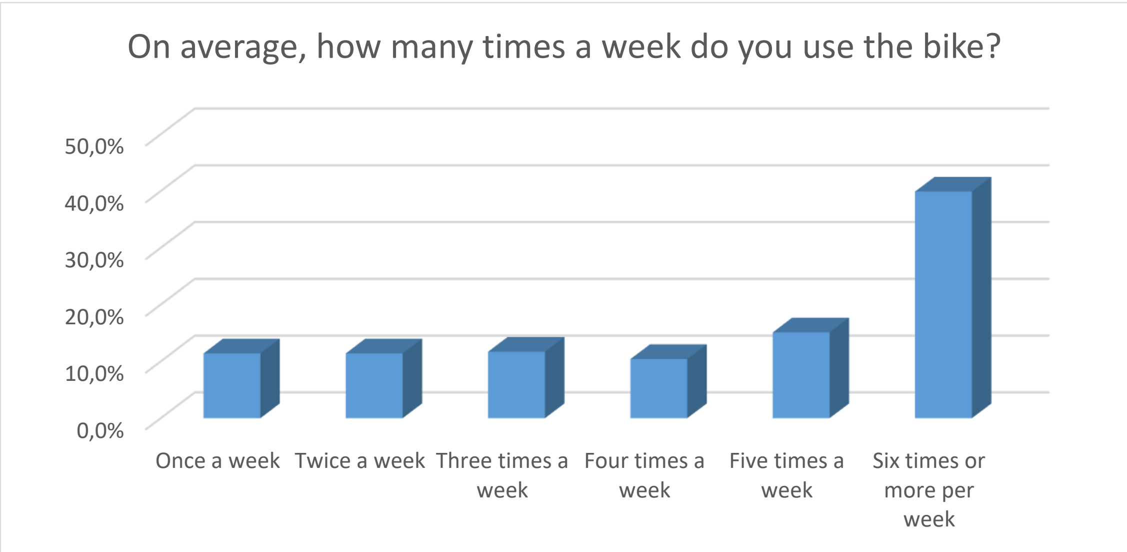

Figure 2. Percentages of Weekly Bicycle Use

2.3. Measures

The web-based questionnaire contained questions about cyclists' perceptions of their competence, attitudes towards cycling in mixed traffic, as well as questions on cyclists' demographics and experience. Values of Cronbach's alpha above .70 were considered to be acceptable (Kline, 1999).

Perceived control. Participants' perceived control was measured in terms of perceived cycling skills regarding the use of the bicycle. Four items were taken and adapted from Chaurand and Delhomme's (2013) Perceived Skill Scale. Participants' were asked to indicate agreement with each statement on a 5-point Likert scale (ranging from 1= *I completely disagree* to 5= *I completely agree*). Examples of reported statements are "I'm capable of maintaining control of my bike in any traffic situation" and "I'm capable of maintaining control of my bike at high speed". Cronbach's alpha was .79, thus displaying internal consistency.

Overconfidence. To measure participants' overconfidence regarding their cycling skills, five items were taken and adapted from Chaurand and Delhomme's (2013) Perceived Skill Scale. Participants were asked to rate to what extent they agreed with 5 statements including "I feel I can ride my bicycle better than the average cyclist" and "I can ride my bike properly even when I'm tired". Answers were given on a 5-point Likert scale (ranging from 1= *I completely disagree* to 5= *I completely agree*). The scale demonstrated internal consistency, Cronbach's alpha was .78.

Perceived risk. Participants' perceived risk regarding the interaction with cars when cycling was assessed using three items taken from Chataway et al. (2014). Examples of items are "I feel unsafe due to the proximity of cars behind me" and "I feel unsafe thinking about car doors being opened in my path". The items were measured on a 5-point Likert scale. Cronbach's alpha was .76, which implied acceptable internal consistency.

Bicycle use. Respondents were asked how many times on average per week they were using the bicycle. Participants could choose between "Never", "Once", "Twice", "Three times", "Four times", "Five times", "Six or more times".

Avoidance to cycle in mixed traffic. To assess participants' avoidance to cycle in mixed traffic, we used three items. Examples are "I avoid cycling in zones where cars pass close to me." and "When there is no separate cycle path, I prefer to use other transport modes." The items were taken and adapted from Chataway et al. (2014). Participants were asked to rate their agreement with the proposed statements on a 5-point Likert scale ranging from 1= *I completely disagree* to 5= *I completely agree*. Cronbach's alpha was .89, thus displaying internal consistency.

Near Miss. To obtain a measure of near miss, we used one single item: "In this past year, have you been close to getting involved in a crash (either with other road users or a single crash) while you were using your bike?" (*0= No, it never happened to me, 1= Once, 2= Twice, 3= Three times, 4= Four times or more*).

2.4. Statistical Analysis

We computed the mean values of the different subscales to use them in the statistical analysis. Descriptive statistics and correlations were estimated using SPSS version 23 (IBM, 2015). Perceived control, overconfidence, avoidance to cycle in mixed traffic and perceived risk were treated as continuous variables, whereas bicycle use and near misses were ordered/categorical ones (i.e. they were not treated as count variables since they both had categories such as "six or more times" or "four times or more"). To estimate the model we used path analysis, a technique of the Structural Equation Modelling family that is used to estimate parameters of relationships between observed variables (Kline, 2016). Other studies have applied Structural Equation Modelling to the study of traffic safety (e.g. Chataway et al., 2014; Xie, Ozbay, & Yang, 2017). Path analysis comprises endogenous variables, which can be outcome variables and/or predictors, and exogenous variables, which are solely (at least in the model) predictors. Moreover, unlike regression, path analysis allows to estimate all the model parameters at the same time, which is a more efficient method of estimation and provides more reliable estimates (Kline, 2016).

In the present study, path estimates, which can be interpreted as regression coefficients (Kline, 2016), and moderation effects were estimated using Mplus version 7 (Muthén & Muthén, 1998-2015).

Mediation responds to the question of ‘how’ or ‘by which means’ a variable exerts an effect over another one (Preacher & Hayes, 2008). For instance, when *M* acts as a mediator between the predictor *X* and the outcome *Y*, the effect of *X* on *Y* is transmitted, either partially or totally, throughout the effect of *X* on the mediator *M*, and the effect of the latter on the outcome *Y*. The effect exerted by *X* on *Y* throughout the mediator *M* is called *indirect effect*, whereas that effect not transmitted through the mediator is called *direct effect*. The sum of both indirect and direct effect is called *total effect* (Hayes, 2009; Preacher & Hayes, 2008).

Given continuous mediator *M*, predictor *X* and outcome *Y*, a mediation effect is represented as:

$$M = i_M + aX + e_M \quad (1)$$

$$Y = i_Y + c'X + bM + e_Y \quad (2)$$

Where i_M and i_Y are the intercepts of *M* and *Y* respectively, e_M and e_Y are the estimation errors, and *a*, *c’*, and *b* are the regression coefficients (Hayes, 2015). The product between *a* and *b* corresponds to the estimate of the indirect effect. Moreover, an indirect effect is assumed to take place when an inferential test allows for assumption that it is different from zero (Hayes, 2015). Then, one can say that the mediation of *X* on *Y* throughout the mediator *M* takes place.

A variable is said to moderate the effect between two other variables (i.e. predictor and outcome) when such the strength or sign of such effect depends on the first variable or moderator (Hayes, 2013). Finding a moderation effect of a quantitative variable does entail to find a linear relationship between the moderator and the relationship between the predictor and the outcome. Identifying an interaction helps understand the conditions under which the relationship between the predictor and the outcome differ, in other words, it helps clarify the 'when' a relationship differs (Hayes, 2013; 2015).

Considering the continuous nature of predictor *X*, outcome *Y* and moderator *Z*, the relationship between *X* and *Y* moderated by *Z* is usually represented as:

$$Y = i_Y + b_1X + b_2Z + b_3XZ + e_Y \quad (3)$$

Where b_1, b_2, and b_3 are regression coefficients, i_Y is the intercept of *Y* and e_Y is the error of estimation (Hayes, 2015). The relationship between *X* and *Y* is then considered to be moderated by *Z* when the regression coefficient of *XZ* is statistically different from zero (Hayes, 2015).

To estimate effects that are both meaningful and interpretable, and to overcome nonessential collinearity between variables and their interaction terms, the variables that are interacting need to be mean centred (Cohen, Cohen, West, & Aike, 2003; Hayes, 2013). Therefore, when estimating the path model, we substituted the variables of the model by their mean centred equivalents in the Mplus script. To calculate the region of significance, that is, the values of the moderator (i.e. perceived control) for which the relationship between predictor (i.e. risk perception) and outcome (i.e. avoidance of mixed traffic) is significantly different from zero, we used the online tool provided by Preacher et al. (2006).

Regarding the estimator, we decided to use Bayesian estimation because it can be applied even when variables are not normally distributed (Muthén, 2011). Moreover, Bayesian analysis estimates the lower and upper values (also known as credible intervals) within which, providing a confidence level in terms of probability, the actual parameter can be found for the observed data (Zyphur & Oswald, 2013). Thus, if credible intervals do not include zero, one can assert that the parameter is different from it (i.e. smaller or bigger than zero, depending on the sign of the parameter and credible interval), and comprised within the values of the credible interval, provided the confidence level. Given the statistical conventions, we use a 95% confidence level to estimate the credible intervals.

3. Results

3.1. Preliminary Analyses

An exploratory factor analysis revealed that each item loaded on its respective factor, thus indicating the underlying processes creating correlations among items (Tabachnick & Fidell, 2013) that provides support for the discriminant validity of the scales. In other words, it has allowed for concluding that all the subscales are measuring different constructs, just as it was expected. Due to the violation of assumptions of normality distribution of all the model variables, we used Spearman rho (i.e. Spearman rank correlation coefficient) to estimate the intercorrelations.

Table 1 displays the mean scores (with relative standard deviations) and the correlation coefficients. The internal consistency of all factors was acceptable being all above .70. We did not assess the internal consistency for bicycle use and near misses since they were single-item variables with multiple choices. The mean responses obtained for the items belonging to perceived control, overconfidence, risk perception of interaction with cars, and bike use were above the midpoint (i.e. above 3 in a scale from 1 to 5), whereas avoidance of mixed traffic and experience of near crashes in the last year were below the midpoint. All the correlations with perceived control were significant except those with age and risk perception of interactions with cars. With regard to the latter, the only significant correlations were with near crashes and age. Overconfidence was positively correlated with perceived control and bicycle use while it was negatively correlated with avoidance of mixed traffic. The latter was negatively correlated with all the variables included in the analyses, except with risk perception of interactions with car and age, which did not achieve the level of statistical significance. All the correlation coefficients with near misses reached the level of statistical significance except the ones with overconfidence and age, which were positively correlated with risk perception of interactions with cars only.

Table 1.

Correlations (Spearman rho) Between Variables in the Path Model.

		M	SD	1	2	3	4	5	6
1.	Perceived Control	3.61	0.79						
2.	Risk Perception of Interactions with cars	3.52	0.88	-.026					
3.	Overconfidence	3.71	0.69	.591**	-.031				
4.	Avoidance of Mixed Traffic	2.46	1.08	-.282**	.009	-.356**			
5.	Bicycle Use	5.26	1.81	.168**	.092	.167**	-.425**		
6.	Near Misses	1.32	1.37	.160**	.278**	.073	-.205**	.286**	
7.	Age	42.46	14.71	.056	.138*	.001	.108	.032	-.019

Note. * $p < .05$; ** $p < .001$. Range 1 to 5 for variables 1-4.

3.2. Path Model

To find the path estimates, we used 30000 iterations and two chains of the Markov Chain Monte Carlo algorithm. Figure 3 displays the Bayesian estimates of the path analysis as well as the moderation estimate. Squared brackets next to each path estimate correspond to the credible intervals obtained by Bayesian estimation. Table 2 displays the hypotheses and whether or not the results provide support for them. All the hypothesised paths were different from zero, with some variation in the strength of the path estimates, and the relationships had the expected signs except for the paths from perceived control to bicycle use (Hypothesis 4) and avoidance of mixed traffic (Hypothesis 5), as well as that from risk perception on the latter (Hypothesis 3), which were not significant.

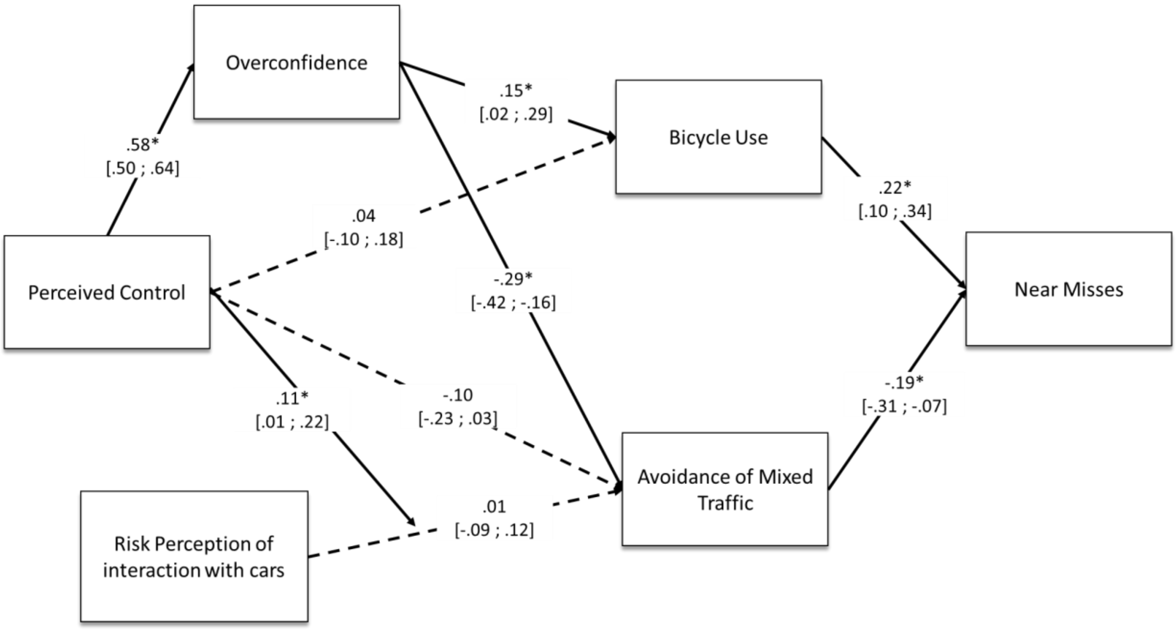

Figure 3. Model with path and moderation estimates and 95% credible interval. Dotted lines are associated with a path whose credible intervals included zero. Coefficients of indirect effects (i.e. Hypotheses 9, 10 and 11) are reported in the text.

Table 2.

Hypotheses and support provided by the data.

Hypotheses	Hypothesised path	Support provided
H1	Avoidance of mixed traffic negatively associated to near misses.	Yes.
H2	Bicycle use is positively associated with near misses.	Yes.
H3	Risk perception of the interaction with motorised vehicles is positively associated with avoidance of mixed traffic.	No.
H4	Perceived control is positively associated with weekly bicycle use.	No.
H5	Perceived control is negatively associated with avoidance of mixed traffic.	No.
H6	Perceived control is positively associated with overconfidence.	Yes.
H7	Overconfidence is negatively associated with avoidance of mixed traffic.	Yes.

H8	Overconfidence is positively associated with bicycle use.	Yes.
H9	The relationship between perceived control and bicycle use is mediated by overconfidence.	Yes.
H10	The relationship between perceived control and avoidance of mixed traffic is mediated by overconfidence.	Yes.
H11	The relationship between perceived control and near misses is mediated by overconfidence, avoidance of mixed traffic and bicycle use.	Yes.
H12	The relationship between risk perception associated with motorised vehicles and avoidance of mixed traffic is moderated by perceived control.	Yes, but the direction of the moderation was not the expected one.

Furthermore, results provide support for hypotheses 9, 10, and 11, which referred to the indirect effects of control to bicycle use (Bayesian estimate= -.24, 95% CI -.36, -.13), and to avoidance of mixed traffic (Bayesian estimates= -.21, 95% CI .02, .40) throughout overconfidence, and to near misses (Bayesian estimates= .15, 95% CI .07, .24) through overconfidence, bicycle use and avoidance. Moreover, perceived control did not have a direct effect either on bicycle use or on avoidance of mixed traffic, but only indirect effects throughout overconfidence.

In addition, results confirmed that there was a significant interaction of perceived control on the relationship between risk perception of interaction with cars and avoidance of mixed traffic (Bayesian estimate=.11, 95% CI = .01, .22). Since hypothesis 3 was not corroborated, risk perception did not predict avoidance of mixed traffic. Nevertheless, the support provided for hypothesis 12 allows for assertion that risk perception did have a direct effect on avoidance of mixed traffic when considering it as a function of the level of perceived control. Figure 4 displays the slope of the relationship between risk perception of interaction with cars and avoidance of mixed traffic for three different values of the moderator (i.e. perceived control). Each three values are distal 1 *SD* from the next one, being ‘Medium control’ the mean of perceived control.

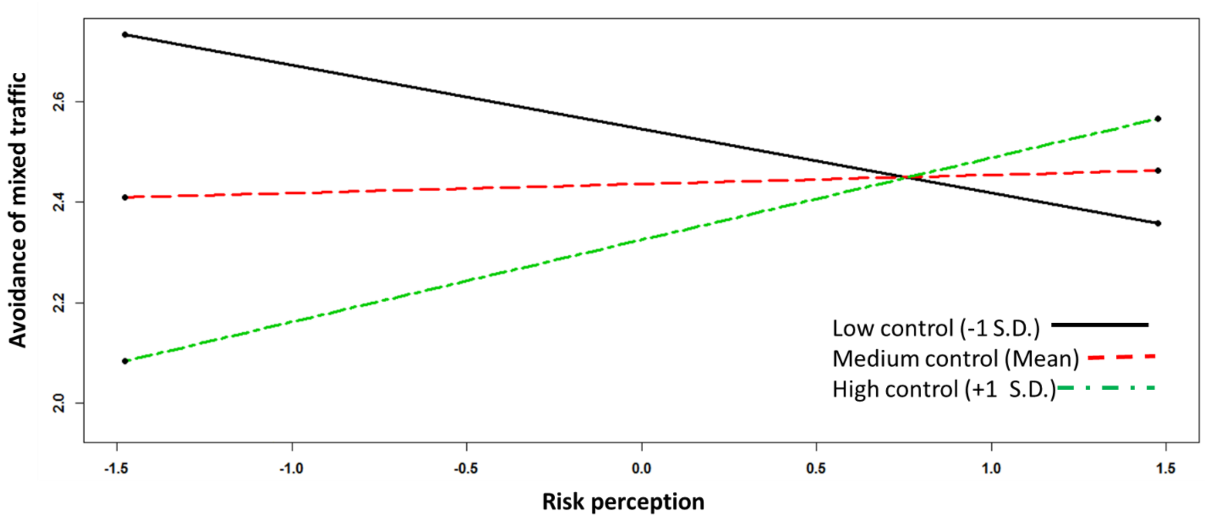

Figure 4. Moderating effect of perceived control.

Figure 5 displays the confidence bands (i.e. values of the moderator) from which the simple slope (i.e. the regression coefficient between perceived risk and avoidance of mixed traffic) is significantly different from zero. The bounds of the confidence bands were lower bound = -6.89, and upper bound = 1.09. This entails that the slope would only be significant for values of perceived control outside those bounds. Nevertheless, since perceived control did not have values as low as the lower bound, we tailored the scale of the graph by zooming in and omitting the lower bound. At this point, it is worth reminding that perceived control had been mean centred for conducting the present analysis.

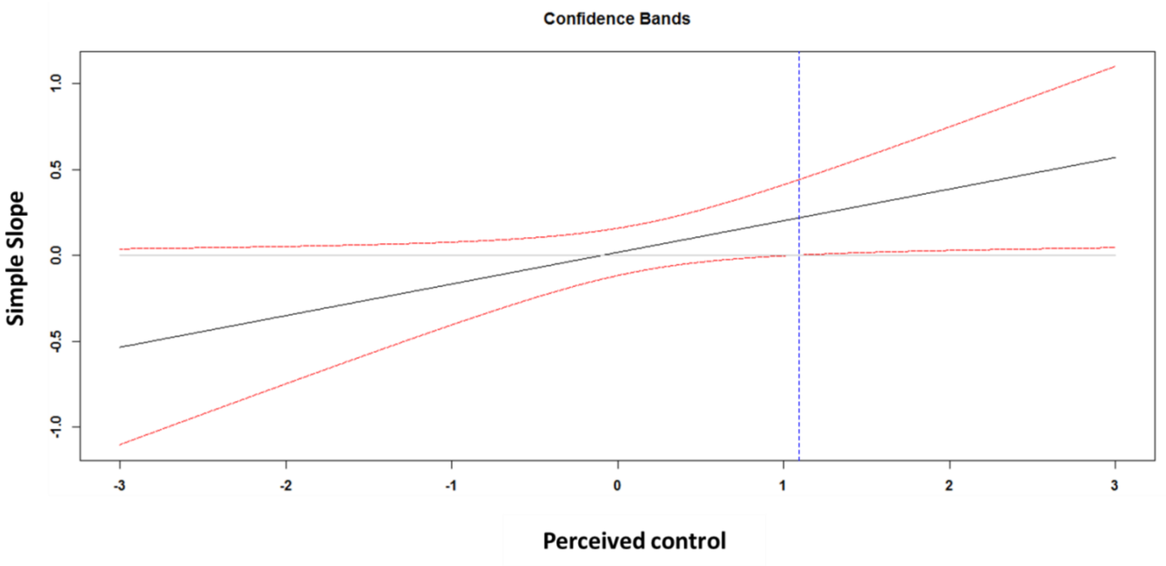

Figure 5. Confidence bands and region of significance

From these results, we can infer that only for relatively high values of perceived control the relationship between risk perception and avoidance of mixed traffic is significantly different from zero. Moreover, as can be seen in Figure 4, the sign of such relationship is positive for such values of the moderator.

4. Discussion

The present study investigated the interactions between perceived competence and risk perception and their effect on cyclists' involvement in risky situations and safety outcomes in cycling.

The results provided support for all the hypotheses except for Hypotheses 3, 4 and 5. Path analysis showed a significant positive association between bicycle use and near misses, thus supporting Hypothesis 2. This finding is in line with previous studies that highlighted a positive association between crash risk and other exposure measures such as time spent cycling, distance travelled (Carlin et al., 1995) or days per week commuting by bike (Bacchieri et al., 2010). On the other hand, the results confirmed the existence of a negative association between avoidance of mixed traffic and near misses, as advanced by Hypothesis 1. In other words, the direct path confirmed that avoiding cycling in mixed traffic can decrease the occurrence of near misses, thus, reducing the relative risk inherent to such situations, as previously found by Pucher (2001; Pucher & Dijkstra, 2000). As we mentioned, this can be better understood considering the Italian context, which is a country with a relative underdevelopment of cycling infrastructure and low bicycle share. Pucher and Dijkstra (2000) argued that north European countries (e.g. The Netherlands and Germany) achieved reductions in bicycle crashes mostly thanks to interventions aimed at decreasing the interaction between non-motorised road users and motor vehicles such as an urban design sensitive to the needs of non-motorists, traffic-calming of residential neighbourhoods and restrictions on motor vehicle use in cities. The present study supports this notion and bolsters the idea that Italian (and other emerging cycling countries) institutions and decision makers should strengthen their effort in creating a more "cycling friendly" country. A way to do so is implementing more interventions both from the infrastructural (e.g. addressing cyclists more in traffic signalling and in urban planning, building cycling facilities) and traffic management (e.g. increasing traffic calmed areas) perspective (see also Bonham & Johnson, 2015), as well as regarding attitudes and behaviour towards cyclists, which have been considered by cyclists to be crucial to their own safety (Aldred, 2016).

We advanced that perceived control would have a direct effect on the avoidance of mixed traffic (Hypothesis 5). Path analysis did not show such direct effect. Based on the results, it may be helpful to explain this absence of a direct effect by focussing on the following hypotheses (i.e. Hypothesis 6). Therein we proposed that perceived control would have a direct effect on overconfidence, due to a biased perception of one's own cycling skills. Biased perception of driving skills has been found to result in an illusory self-assessment of driving skills (McKenna, 1993). Consistently, path analysis showed a direct effect of perceived control over cycling ability on overconfidence (thus supporting Hypothesis 6), which can result in a biased risk assessment leading to high levels of risk acceptance (Sümer et al., 2006). Path analysis also showed a negative direct effect of overconfidence on avoidance of mixed traffic, supporting Hypothesis 7. As a consequence, we found an indirect effect of perceived control on avoidance of mixed traffic situation, through overconfidence (Hypothesis 10). In a nutshell, cyclists with higher perceived control over the bicycle might overestimate their own skills (i.e. more overconfidence) to deal with riskier traffic scenarios, such as riding in mixed traffic, or to handle the potential consequences of external sources of risk, such as interaction with other road users. Previous research showed that both drivers and cyclists have shown to adopt risky behaviour as they felt to have control over their behaviour on the road (Castanier et al., 2013; Cristea & Gheorghiu, 2016). In our study, regardless of the direct effect, the consequences of perceived control on the acceptance of riskier traffic scenario are explained through an indirect effect that mediates the relationship.

Regarding the relationship concerning control and bicycle use, in Hypothesis 4, we established the role of perceived control over one's riding as a predictor of weekly rate of bicycle use. Nevertheless, path analysis did not show such a direct path. As aforementioned, perceived control predicted overconfidence, and path analysis showed a direct effect of overconfidence on bicycle use, thus confirming Hypothesis 8. In other words, cyclists with higher overestimation of their own skills tend to use more the bicycle as a means of transportation. Thus, what emerged as determinant in predicting bicycle use when considering one's own ability to control a specific situation, is the indirect effect of the perceived control of the bike on bicycle use through overconfidence (Hypothesis 9).

In other words, considering the inherent risk of involvement in mixed traffic, this study explores more deeply this relationship, highlighting the role of overconfidence as a possible mediator, predicting the potentially false belief of feeling in control over the bicycle. This could easily lead to a higher involvement in mixed traffic situations and more use of the bicycle, which brings about a higher probability of experiencing a near crash due to reckless conduct, as proposed in Hypothesis 11. Path analysis showed a significant indirect effect of perceived control on near misses throughout the influence of overconfidence, and consequently on bicycle use and avoidance of mixed traffic.

In Hypothesis 3, we proposed that cyclists' risk perception regarding the interaction with motorised vehicles would affect their avoidance of mixed traffic, that is, the higher the perceived risk in riding with motorised traffic, the less a person would cycle in those situations, showing different degrees of avoidance behaviour. Path analysis did not show a significant direct effect of risk perception on avoidance behaviour, thus not providing support to hypothesis 3. This result contrasts with previous studies (Chataway et al., 2014; Kaplan & Prato, 2016) which found that fear of traffic (i.e. perceived risk of interaction with cars), was a barrier to cycling especially in urban areas, in particular for non-frequent users and recreational cyclists. Yet, our findings suggest that risk perception regarding the interaction with motorised vehicles cannot explain the adoption of avoidance behaviour by cyclists on its own, but it does so under certain circumstances. These seem to be defined by perceived control, in that only for higher levels of perceived control does risk perception predict the actual avoidance of mixed traffic situations in the hypothesised direction (Hypothesis 3). This is derived from testing Hypothesis 12, which proposed that perceived control would moderate the relationship between risk perception and avoidance of mixed traffic. Despite finding such moderation, the interpretation thereof does not comply with the directions hypothesised. We had foreseen that for higher levels of control, the relationship between risk perception and avoidance would have been weaker due to the higher reliance on one's own skills to face hazardous situations. Nevertheless, our findings make manifest an underlying cause other than expected. A possible interpretation of such effects displayed in Figure 4 and 5 is that only when cyclists perceive they possess enough mastery of the bicycle, they take actions to avoid the risks inherent to mixed traffic as a function of the perceived risk. This does not mean that they do not take any actions regarding the risky situation when they have lower levels of control, it means though that in such conditions it is not a function of perceived risk. As a matter of fact, as previously discussed, regardless of the levels of perceived control, cyclists tend to generally avoid risks as a function of both perceived control and overconfidence. In other words, cyclists with low levels of control and high levels of risk perception will tend to avoid risks because of the low levels of control, but not because risk perception is high. These findings help to understand the interaction between the perceived risk when cycling with motorised vehicles, the perceived control over the bicycle and the avoidance of those traffic situations.

4.1. Implications

On the one hand, the results of the present study may enrich the interpretation around the behavioural adaptation phenomenon from a theoretical point of view. Several definitions of behavioural adaptation have been proposed so far. Generally, when a change occurs in the vehicle, in the road environment or in the driver's own skills, a reaction to these changes is expected by the driver, thus running the risk of not exploiting potential safety gains (Rudin-Brown & Jamson, 2013; Summala, 2005). The findings of the present study, may help to better understand the adaptation to risk throughout the role of perceived control, whose effect is explained by overconfidence. The more road users feel in control over their means of transport (i.e. bicycle) and surrounding traffic due to experience, the more they will increase confidence in their skills (Summala, 2005). Cyclists with higher overestimation of their own skills may adapt their behaviour in a way that can lead to interpreting dangerous or hazardous situations (e.g. committing a violation) as relatively less risky, as well as feeling more capable to deal with them or to handle the potential consequences of external sources of risk, such as interaction with other road users (Rudin-Brown & Jamson, 2013). This behavioural adaptation to the perceived control might backfire on safety outcomes, especially in mixed traffic scenarios.

On the other hand, our study has several practical implications. We have found that perceived control and overconfidence put people in a more vulnerable position (i.e. at risk) throughout the effect on bicycle use and avoidance of risky situations. Therefore, we advocate for finding a compromise between the increase of cycling levels, which can lead to the safety in number effect (Elvik & Bjørnskau, 2017) as well as health benefits (Oja et al., 2011), and the avoidance of mixed traffic. This way, one would expect the decrease in interaction with motorised vehicles to lead to a reduced number of crashes due to interaction with motorised vehicles, which constitute a more dangerous type than those against non- motorised vehicles (Siman-Tov et al., 2010; XCYCLE, 2016). One way to attain this would be by an improvement and enlargement of cyclists devoted infrastructure which provided more available and attractive choices for cyclists, thus reducing the need to getting involved in mixed traffic situations. Moreover, we propose that this could be combined with strategically acting upon the perceived risk in mixed traffic situations and cyclists' perception of control. Some ways of raising awareness of one's (lack of) control over the bicycle in risky situations and increasing risk perception of cyclist-motorised vehicle interaction could be educational campaigns (Guttman, 2015; Nathanil & Adamos, 2013). It could be argued that increasing risk perception levels in the cyclist population could be counterproductive because it would prompt people to use other modes of transportation. Nevertheless, we propose that this should be done while providing safer urban design alternatives that help reduce the interaction with motorised vehicles (Pucher & Dijkstra, 2000), such as traffic-calming of residential neighbourhoods, restriction on motor vehicle use in cities, or building more cycling tracks, which seems to be preferred by the all sorts of riders in general (Aldred et al., 2017).

Another possible solution to the effect of mixed traffic on safety outcomes resides in the use of new technological advancements, such as those being developed in EU-funded projects like XCYCLE (http://www.xcycle-h2020.eu/). The advent of new safety technologies and cooperative systems represent a great opportunity for helping both cyclists and drivers to adopt safety behaviours in mixed traffic situations. On-bike and in-vehicle devices/systems are spreading all over the market and are becoming increasingly more accessible in terms of price and customizability. Such technologies should be designed to foster the adoption of safe behaviours (e.g. reducing speed in proximity of crossroads or bicycle crossings, respecting a safety passing distance, etc.) both by cyclists and motorised vehicle drivers.

Finally, with these combined solutions (i.e. foster cycling infrastructure, risk awareness campaigns and technological support for cyclists and drivers), we want to stress that cyclists' safety cannot be reduced only to one party's blame. In fact, it is a complex, multi-faceted issue that ought to be addressed with a holistic approach.

4.2. Limitations and Future Research

Since this research is questionnaire based, the study features some limitations. The main ones are that it relies on self-assessment, the common method variance (Podsakoff et al., 2003) and the memory decay of near misses (Bradburn et al., 1987; Chapman & Underwood, 2000). Common method variance concerns the fact that when using the same measurement methods for all the variables, some of the variance between them might be attributable to such method.

With regard to suggestions for future research, the construct of perceived control has a myriad of nuances. For instance, whether the control concerns the consequences of the risk or the possibility to avoid it (Nordgren et al., 2007), whether control regards the specific situation at hand (i.e. involvement in mixed traffic) or a more general sense of self-efficacy. Therefore, we propose that future research should investigate how the different types of perceived control would affect the relationship between perceived risk and avoidance of such risk.

In addition, future research should investigate whether the moderation found in the present study holds up for different situations (e.g. intersections) and specific scenarios, and how it could affect route choice. Moreover, future research should bear in mind the different type of near misses, such as against a motorised vehicle or not, and the role of the different types of perceived control on the occurrence of each type of near miss. It should also consider the use of latent variables instead of only observed variables to take proportional consideration of the most important indicators (Kline, 2016).

Even if it has been shown that the perception of control over certain situations can act as a spur to execute a given behaviour such as riding a bike (Chaurand & Delhomme, 2013; Cristea & Gheorghiu, 2016; Lois et al., 2015), other bicycle-related factors might directly intervene in the relationship with bicycle use. The literature has revealed a comprehensive set of variables which are relevant to use of the bicycle (Parkin et al., 2008), especially when considering those people that use the bicycle as their main means of transport (Heinen et al., 2010). These factors comprise: socio-economic, psychological, environmental and transport related variables have been shown to influence bicycle use. It was not the intention of this study to discuss on these determinants, nevertheless, to give an extended overview of the main factors influencing bicycle use, future research should focus on how such factors determine the model presented in the present article. Moreover, future research should take into account whether cyclists come from and cycle in urban or rural areas, as well as the amount of motorised transport present in the streets, which plays an important role in cyclists' safety (Heydari et al., 2017).

As suggested in the implications, new safety technologies may play an important role in the way cyclists interact in mixed traffic. Nevertheless, more research is needed to understand to what extent each particular design brings about safer cycling and how it influences the perception of risk and control.

5. Conclusion

The present research investigated the complex relationship between perceived control, perceived risk and the causal paths through which they influence near miss occurrence. The findings showed that perceived control increased overconfidence in one's skills and this increased exposure to cycling and mixed traffic. As a result, perceived control affected (i.e. increasing) the occurrence of near misses through bicycle use and involvement in mixed traffic. Moreover, the relationship between perceived risk and avoidance of mixed traffic was moderated by perceived control insofar as only for relatively high levels of control, perceived risk increased the avoidance of mixed traffic. The results have implications regarding the understanding of the role played by overconfidence on the effect of control on bicycle use and avoidance of mixed traffic, as well as about the circumstances when risk perception affects risk acceptance.

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APPENDIX A. Items of each subscale.

Avoidance of mixed traffic (Completely disagree/Completely agree):
1. When there is no segregated cycle path, I prefer to use other transport modes.
2. I avoid cycling in mixed traffic during the morning/afternoon peak period.
3. I avoid cycling in zones where cars pass close to me.

Risk perception (Never/Always):
1. I feel unsafe due to the proximity of cars behind me.
2. I feel unsafe due to the proximity of cars beside me.
3. I feel unsafe thinking about car doors being opened in my path.

Perceived control (Completely disagree/ Completely agree):
1. I have no problem adapting my riding to road surface conditions.
2. When on my bike, I control my riding no matter how heavy the traffic is.
3. When on my bike, I control my riding no matter what the weather is like.
4. When on my bike, I control my riding no matter how fast I'm going.

Overconfidence (Completely disagree/ Completely agree):
1. I am sure of myself when riding.
2. I easily make my way between other vehicles.
3. I ride better than the average cyclist.
4. I can drive well even when I'm tired.
5. I have good reflexes.