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The Role of Perceived Competence and Risk Perception in Cycling Near Misses

Word count: 8347

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.*

78 **1. Introduction**

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

90 **1.1. Crashes and Near Misses among Cyclists**

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

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

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

123 In the cycling domain, the relationship between near misses and crashes is yet to be
124 understood. In accordance with Güttinger's (1982) model, Aldred (2016) suggests that near
125 miss incidents may provide 'early warnings' of situations or behaviour that could lead to
126 crashes. Moreover, Aldred (2016) compared percentages of attribution of near misses and

127 crashes in the study of Knowles' et al. (2009) and found that they were very similar, giving
128 support to the shared causation.

129 Despite these early studies, cycling near misses remain under-researched, regardless of
130 their likely contribution to injury crashes (Aldred, 2016). Nevertheless, more and more
131 innovative solutions and methodologies attempted to address such matter (i.e. Aldred &
132 Crossweller, 2015; Westerhuis & De Waard, 2016). Some studies, such as Aldred and
133 Crossweller (2015), and Joshi, Senior, and Smith (2001) in the UK, and Sanders (2015) in the
134 San Francisco Bay Area, have also shown that near misses are a very common experience for
135 cyclists. For example, using an online diary methodology, Aldred and Crossweller (2015) found
136 that the 75% of participants experienced at least .75 incidents per cycled hour, with a median
137 of 1.71 per hour. Similarly, using a self-reported questionnaire, Sanders (2015) showed that
138 86% of those who bicycle at least annually in this sample had experienced some type of near
139 miss.

140 **1.2. Cycling Levels and Avoidance of Mixed Traffic as Exposure**

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

146 In the present study, we consider exposure at two different levels: (1) exposure to
147 cycling in general, that is to say, use of the bicycle; and (2) cycling in mixed traffic situations.
148 The latter type of exposure allows for more opportunities for cyclists to interact with cars,
149 which is of especial importance when considering risk. Evidence shows countries and cities
150 with extensive bicycling facilities have the highest cycling modal split shares and the lowest
151 fatality rates (Pucher, 2001; Pucher & Dijkstra, 2000). Those countries and cities without

152 separate facilities have low modal split shares and much higher fatality rates (Buehler & Dill,
153 2016; Pucher & Dijkstra, 2000). However, in emerging cycling regions where cyclists are
154 rapidly growing in number, cyclists are forced to share the road with motorised vehicles due to
155 the underdevelopment of cycling infrastructure (e.g. Pucher et al., 2011). Cyclists in urban area
156 may have to choose between (1) cycle within mixed traffic situations with shorter travel time,
157 (2) cycle on bike lanes or segregated paths with a longer travel time, and (3) use other means
158 of transport. The two latter options would imply avoiding mixed traffic and, therefore, the risk
159 of conflicts with road users in it.

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

167 **1.3. Risk Perception of Interaction with Cars**

168 Risk-adaptation theory proposes that road traffic risk perception depends on fear and
169 arousal (Koornstra, 2009). Cyclists feel most secure on road with cycle tracks and most at risk
170 on roads with mixed traffic, while cycle lanes can be considered half way: less secure than
171 cycle tracks, but considerably more secure than mixed traffic roads (Jensen et al., 2007). In
172 particular, it has been shown that the presence and the size of motor vehicles (Aldred, 2016)
173 increase cyclists' feeling of being at risk. Moreover, previous experiences set up the adaptation
174 level around which there is a range of indifference to risks (Koornstra, 2009). Such level and
175 ranges vary between individuals; therefore, one can also expect variance in the degree of risk
176 which cyclists incur depending on their own personal characteristics, leading to potential

177 compensations (Koornstra, 2009; Wilde, 1982) in terms of strategic decisions (e.g. taking the
178 bicycle over other means of transport, choosing one path to work instead of another) or driving
179 behaviours (e.g. riding at a certain speed, committing violations or not, keeping safe or unsafe
180 distance from other road users). This way, avoiding mixed traffic can be a strategy to cope with
181 perceived risk (Chataway et al., 2014; Kaplan & Prato, 2016; O'Connor & Brown, 2010)
182 which, as other forms of behavioural adaptation, might lead to a decrease of the objective
183 probability of crash or events with potential hazards (Ba et al., 2016). Therefore, we
184 hypothesised that risk perception regarding interaction with motorised vehicles will be
185 positively associated with avoidance of mixed traffic (Hypothesis 3). In other words, the higher
186 the perception of risk in interactions with motorised vehicles, the more cyclists will avoid
187 mixed traffic situations.

188 **1.4. Perceived Competence**

189 Perceived competence in riding a bicycle can be considered as a form of control over
190 one's riding (Chaurand & Delhomme, 2013). Cristea and Gheorghiu (2016) found that
191 perceived behavioural control over certain situation was a good predictor of the behavioural
192 intention to take part in such situations. Perceived behavioural control refers to the individual's
193 perception of his or her ability to execute a given behaviour (Ajzen, 1991). According to this,
194 people will likely choose to perform behaviours they think they will be capable of executing.
195 The concept of perceived behavioural control is very similar to that of self-efficacy (Bandura,
196 1982) and it captures people's perceived capability to execute a given behaviour, for example,
197 travelling to work by bicycle (Lois et al., 2015). With that said, perceived control can be defined
198 as a self-perception regarding the own capabilities and ability to control one's own action to
199 execute a given behaviour, in other words, how skilled and effective people perceive
200 themselves to be given particular conditions. According to this framework it is reasonable to
201 argue that perceived control will influence how much a person will engage in a certain

202 behaviour. In the context of the present study, we hypothesise that increasing levels of
203 perceived control will be positively associated with weekly rates of bicycle use (Hypothesis 4).

204 Previous studies have found that the perceived control over a driving situation predicts
205 the disposition to take higher levels of risk (Horswill & McKenna, 1999). Moreover, people
206 tend to better accept controllable rather than uncontrollable risks (Nordgren et al., 2007).
207 Furthermore, in driving safety research, a reduced risk avoidance in road traffic has been found
208 when drivers' perception of control is higher (Horswill & McKenna 1999; Windsor et al.,
209 2008). Considering the inherent risk of involvement in mixed traffic and the decision to avoid
210 mixed traffic situations as a coping strategy to reduce the perceived risk (Chataway et al., 2014;
211 Kaplan & Prato, 2016; O'Connor & Brown, 2010), higher perceptions of control may influence
212 cyclist's behavioural intention to ride in a stressful traffic environment such as mixed traffic
213 scenario (Kaplan & Prato, 2016; O'Connor & Brown, 2010). Therefore, we hypothesised that
214 perceived control will be negatively associated with avoidance of mixed traffic (Hypothesis 5).
215 In other words, the higher the perception of control, the more cyclists will be involved in mixed
216 traffic, since they will avoid less.

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

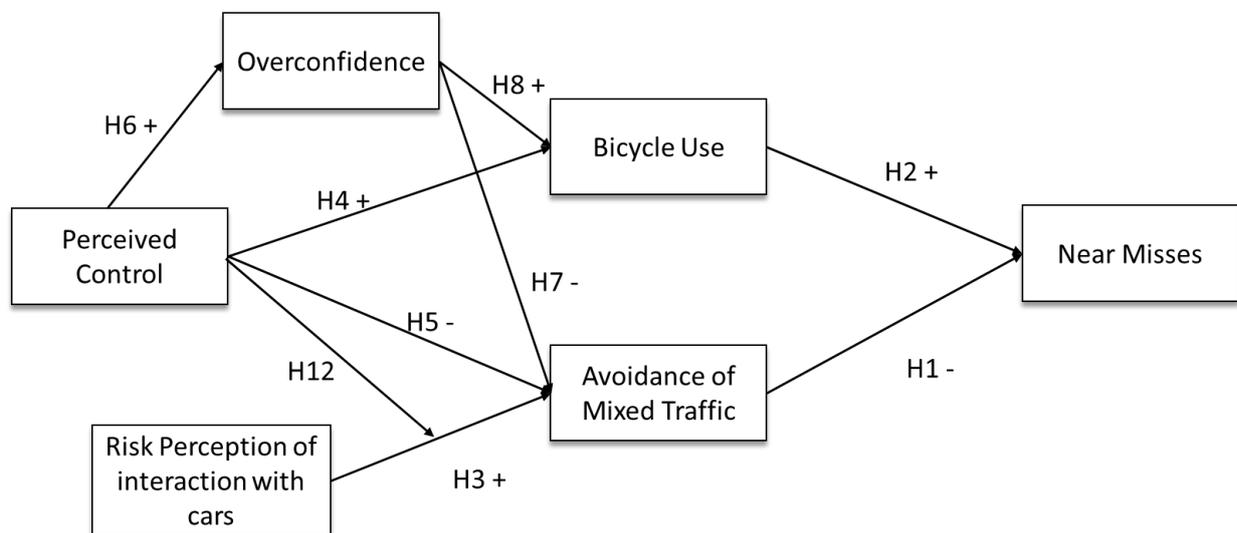
226 the situation and outcomes. Therefore, we hypothesised that perceived control will lead to
227 overconfidence in the person's skills because of unrealistic optimism (Hypothesis 6).

228 Moreover, in driving safety research, overconfidence has been found to be related to
229 riskier behaviours among drivers (Hatfield & Fernandes, 2009; Wohleber & Matthews, 2016).
230 Chaurand and Delhomme (2013) found that higher levels of overconfidence in one's cycling
231 skills were associated with lower risk perception. Thus, cyclists with higher overestimation of
232 their own skills might see dangerous or hazardous situations, such as committing a violation,
233 as relatively less risky. In addition, they will feel more capable to deal with them or to handle
234 the potential consequences of external sources of risk, such as interaction with other road users.
235 Therefore, perceiving oneself as more competent than one actually is, may lead to not avoiding
236 situations that, otherwise, would be considered hazardous. Thus, we hypothesise that
237 increasing levels of overconfidence will be associated with lower avoidance of mixed traffic
238 (Hypothesis 7) as well as with a higher rate of bicycle use (Hypothesis 8). Based on the
239 reasoning presented for hypothesis 6, we established that the relationship between perceived
240 control and bicycle use is indirectly explained through overconfidence (Hypothesis 9) as it is
241 the relationship between perceived control and avoidance of mixed traffic (Hypothesis 10).
242 Finally, in order to further understand the relations between our variables, we expect to find an
243 indirect effect of multiple mediators on the relationship between perceived control and near
244 misses throughout the influence of overconfidence which in turn, will have an effect on near
245 misses through the parallel mediators bicycle use and avoidance of mixed traffic (Hypothesis
246 11).

247 Research addressing perceived control and risk perception has mainly focused on their
248 relationship, raising the need for investigating the possible effect of the latter on risk
249 acceptance. Cordellieri's, et al., (2016) findings suggested that worrying about the risk might
250 influence the reduction of hazardous behaviours. Based on the assumption that trusting one's

251 skills leads to unrealistic optimism (Weinstein, 1980), we propose that for people with high
 252 control over one's own skills, there will be less worry about the risk even if the hazard is
 253 perceived equally risky. Thus, cyclists with higher levels of perceived control might base their
 254 decision to take part in the risky behaviour mainly for reasons other than the level of risk,
 255 because they might be less worried about such a risk. Therefore, we propose that, while risk
 256 perception might be a predictor of acceptance of the risk (i.e. interaction with mixed traffic),
 257 perceived control could play a relevant role in shaping the context in which risk perception is
 258 considered to be important when deciding to take such risk. That is, we hypothesise that with
 259 high levels of perceived control, risk perception will not play an important role in the prediction
 260 of acceptance of the risk, whereas, with lower levels of perceived control, the decision to
 261 engage in the risky behaviour will be made on the basis of risk perception. In other words, we
 262 hypothesise that the relationship between risk perception and avoidance of mixed traffic will
 263 be moderated by perception of control (Hypothesis 12).

264 Figure 1 displays the hypothesised path model.



265
 266 *Figure 1.* Hypothesised Path Model. The characters next to each arrow point out the hypothesis
 267 and the sign of the expected association. Hypotheses 9 to 11 are not included since they foresaw
 268 mediation (i.e. involving more than one arrow).

269 **2. Method**

270 **2.1. Procedure**

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

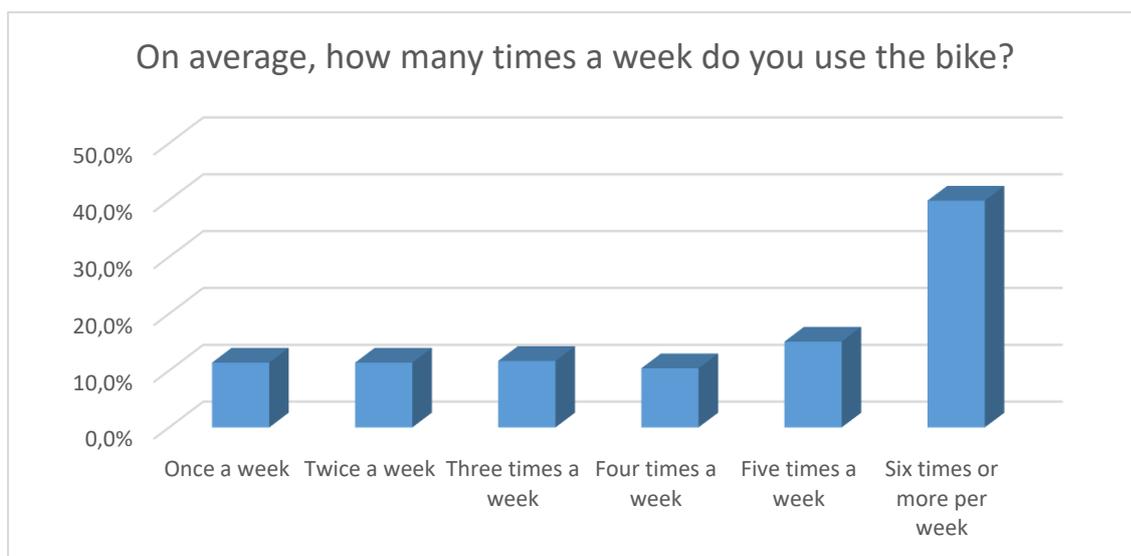
283 Italy is a country with certain regions that have growing cycling levels but that still
284 lacks infrastructure devoted to cyclists in comparison with other European countries with
285 longer cycling traditions. Therefore, it is likely that many people may be forced to choose
286 between getting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

287 **2.2. Participants**

288 A total of 455 participants answered the questionnaire. After considering only those
289 participants who had filled out the items for age, sex and that acknowledged to use the bicycle
290 at least once a week, the remaining sample comprised 298 (65.5%) participants. From these,
291 178 (59.7%) were male, 119 (39.3%) were female and 3 (1.0%) did not identify with male-
292 female categories. The age of the participants ranged from 19 to 72 years. The mean for females
293 was 37.1 ($SD = 14.4$), the mean for males was 45.8 ($SD = 13.9$), whereas the general mean was

294 42.5 ($SD = 14.7$). Moreover, 189 (63.4%) participants were employed, 70 (23.5%) were
295 students, 10 (3.4%) were unemployed, and 29 (9.7%) were retired. Regarding their educational
296 background, more than half of the sample had a Bachelors' or Masters' degree (166, 52.4%),
297 83 (27.8%) had high-school or middle school education and the rest (i.e. 59, 19.8%) had PhD-
298 level studies.

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



305
306 *Figure 2. Percentages of Weekly Bicycle Use*

307 2.3. Measures

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

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

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

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

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

334 *Avoidance to cycle in mixed traffic.* To assess participants' avoidance to cycle in mixed
335 traffic, we used three items. Examples are "I avoid cycling in zones where cars pass close to
336 me." and "When there is no separate cycle path, I prefer to use other transport modes." The

337 items were taken and adapted from Chataway et al. (2014). Participants were asked to rate their
338 agreement with the proposed statements on a 5-point Likert scale ranging from 1= *I completely*
339 *disagree* to 5= *I completely agree*. Cronbach's alpha was .89, thus displaying internal
340 consistency.

341 *Near Miss*. To obtain a measure of near miss, we used one single item: "In this past
342 year, have you been close to getting involved in a crash (either with other road users or a single
343 crash) while you were using your bike?" (0= *No, it never happened to me*, 1= *Once*, 2= *Twice*,
344 3= *Three times*, 4= *Four times or more*).

345 **2.4. Statistical Analysis**

346 We computed the mean values of the different subscales to use them in the statistical
347 analysis. Descriptive statistics and correlations were estimated using SPSS version 23 (IBM,
348 2015). Perceived control, overconfidence, avoidance to cycle in mixed traffic and perceived
349 risk were treated as continuous variables, whereas bicycle use and near misses were
350 ordered/categorical ones (i.e. they were not treated as count variables since they both had
351 categories such as "six or more times" or "four times or more"). To estimate the model we used
352 path analysis, a technique of the Structural Equation Modelling family that is used to estimate
353 parameters of relationships between observed variables (Kline, 2016). Other studies have
354 applied Structural Equation Modelling to the study of traffic safety (e.g. Chataway et al., 2014;
355 Xie, Ozbay, & Yang, 2017). Path analysis comprises endogenous variables, which can be
356 outcome variables and/or predictors, and exogenous variables, which are solely (at least in the
357 model) predictors. Moreover, unlike regression, path analysis allows to estimate all the model
358 parameters at the same time, which is a more efficient method of estimation and provides more
359 reliable estimates (Kline, 2016).

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

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

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

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

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

374 Where i_M and i_Y are the intercepts of M and Y respectively, e_M and e_Y are the estimation
375 errors, and a , c' , and b are the regression coefficients (Hayes, 2015). The product between a
376 and b corresponds to the estimate of the indirect effect. Moreover, an indirect effect is assumed
377 to take place when an inferential test allows for assumption that it is different from zero (Hayes,
378 2015). Then, one can say that the mediation of X on Y throughout the mediator M takes place.

379 A variable is said to moderate the effect between two other variables (i.e. predictor and
380 outcome) when such the strength or sign of such effect depends on the first variable or
381 moderator (Hayes, 2013). Finding a moderation effect of a quantitative variable does entail to
382 find a linear relationship between the moderator and the relationship between the predictor and
383 the outcome. Identifying an interaction helps understand the conditions under which the

384 relationship between the predictor and the outcome differ, in other words, it helps clarify the
385 ‘when’ a relationship differs (Hayes, 2013; 2015).

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

$$388 \quad Y = i_Y + b_1X + b_2Z + b_3XZ + e_Y \quad (3)$$

389 Where b_1 , b_2 , and b_3 are regression coefficients, i_Y is the intercept of Y and e_Y is the error
390 of estimation (Hayes, 2015). The relationship between X and Y is then considered to be
391 moderated by Z when the regression coefficient of XZ is statistically different from zero (Hayes,
392 2015).

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

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

408 interval, provided the confidence level. Given the statistical conventions, we use a 95%
409 confidence level to estimate the credible intervals.

410

411 **3. Results**

412 **3.1. Preliminary Analyses**

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

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

433 the correlation coefficients with near misses reached the level of statistical significance except
 434 the ones with overconfidence and age, which were positively correlated with risk perception of
 435 interactions with cars only.

436

437 Table 1.

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

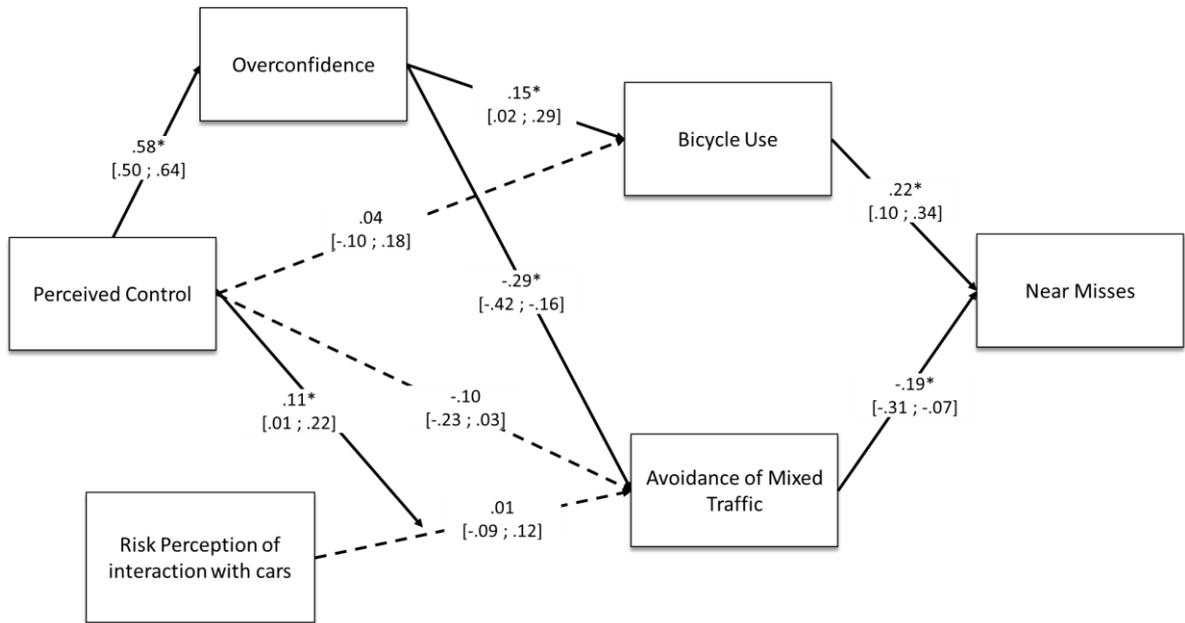
	M	SD	1	2	3	4	5	6
1. Perceived Control	3.61	0.79						
2. Risk Perception of Interactions with cars	3.52	0.88	-.026					
3. Overconfidence	3.71	0.69	.591**	-.031				
4. Avoidance of Mixed Traffic	2.46	1.08	-.282**	.009	-.356**			
5. Bicycle Use	5.26	1.81	.168**	.092	.167**	-.425**		
6. Near Misses	1.32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

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

440 3.2. Path Model

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

450



451

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

455

456 Table 2.

457 *Hypotheses and support provided by the data.*

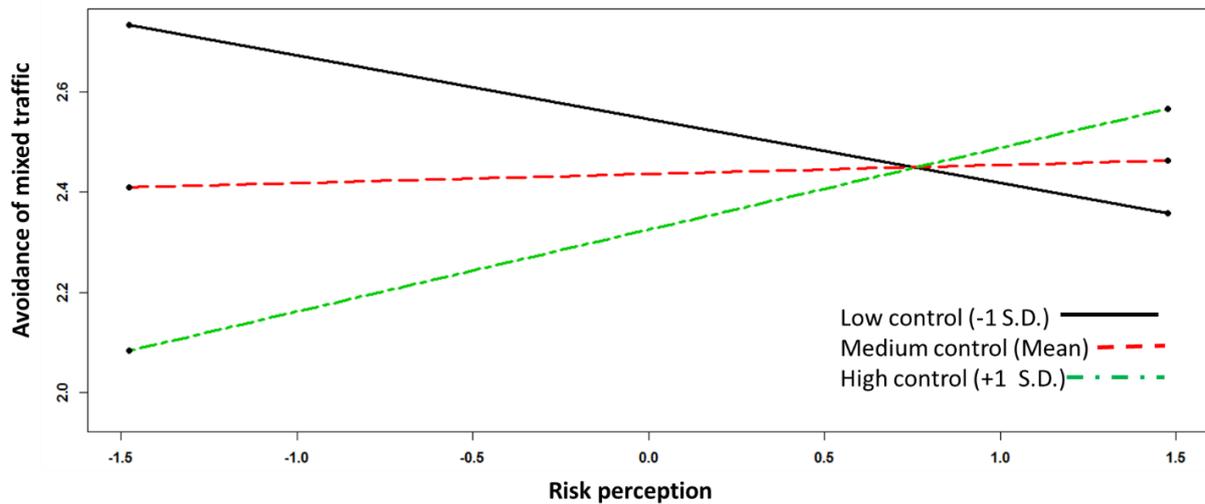
Hypotheses	Hypothesised path	Support provided
H1	Avoidance of mixed traffic negatively associated to near misses.	Yes.
H2	Bicycle use is positively associated with near misses.	Yes.
H3	Risk perception of the interaction with motorised vehicles is positively associated with avoidance of mixed traffic.	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.

458

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

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

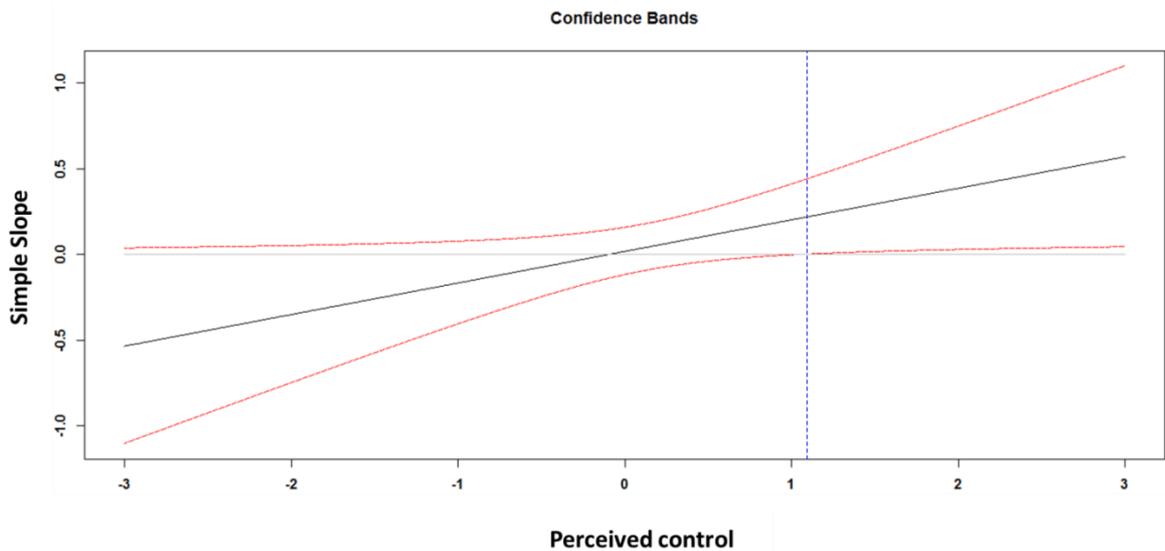


476

477 *Figure 4.* Moderating effect of perceived control.

478

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



487

488 *Figure 5. Confidence bands and region of significance*

489

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

494

495 **4. Discussion**

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

499 The results provided support for all the hypotheses except for Hypotheses 3, 4 and 5.
 500 Path analysis showed a significant positive association between bicycle use and near misses,
 501 thus supporting Hypothesis 2. This finding is in line with previous studies that highlighted a
 502 positive association between crash risk and other exposure measures such as time spent cycling,
 503 distance travelled (Carlin et al., 1995) or days per week commuting by bike (Bacchieri et al.,
 504 2010). On the other hand, the results confirmed the existence of a negative association between

505 avoidance of mixed traffic and near misses, as advanced by Hypothesis 1. In other words, the
506 direct path confirmed that avoiding cycling in mixed traffic can decrease the occurrence of near
507 misses, thus, reducing the relative risk inherent to such situations, as previously found by
508 Pucher (2001; Pucher & Dijkstra, 2000). As we mentioned, this can be better understood
509 considering the Italian context, which is a country with a relative underdevelopment of cycling
510 infrastructure and low bicycle share. Pucher and Dijkstra (2000) argued that north European
511 countries (e.g. The Netherlands and Germany) achieved reductions in bicycle crashes mostly
512 thanks to interventions aimed at decreasing the interaction between non-motorised road users
513 and motor vehicles such as an urban design sensitive to the needs of non-motorists, traffic-
514 calming of residential neighbourhoods and restrictions on motor vehicle use in cities. The
515 present study supports this notion and bolsters the idea that Italian (and other emerging cycling
516 countries) institutions and decision makers should strengthen their effort in creating a more
517 “cycling friendly” country. A way to do so is implementing more interventions both from the
518 infrastructural (e.g. addressing cyclists more in traffic signalling and in urban planning,
519 building cycling facilities) and traffic management (e.g. increasing traffic calmed areas)
520 perspective (see also Bonham & Johnson, 2015), as well as regarding attitudes and behaviour
521 towards cyclists, which have been considered by cyclists to be crucial to their own safety
522 (Aldred, 2016).

523 We advanced that perceived control would have a direct effect on the avoidance of
524 mixed traffic (Hypothesis 5). Path analysis did not show such direct effect. Based on the results,
525 it may be helpful to explain this absence of a direct effect by focussing on the following
526 hypotheses (i.e. Hypothesis 6). Therein we proposed that perceived control would have a direct
527 effect on overconfidence, due to a biased perception of one’s own cycling skills. Biased
528 perception of driving skills has been found to result in an illusory self-assessment of driving
529 skills (McKenna, 1993). Consistently, path analysis showed a direct effect of perceived control

530 over cycling ability on overconfidence (thus supporting Hypothesis 6), which can result in a
531 biased risk assessment leading to high levels of risk acceptance (Sümer et al., 2006). Path
532 analysis also showed a negative direct effect of overconfidence on avoidance of mixed traffic,
533 supporting Hypothesis 7. As a consequence, we found an indirect effect of perceived control
534 on avoidance of mixed traffic situation, through overconfidence (Hypothesis 10). In a nutshell,
535 cyclists with higher perceived control over the bicycle might overestimate their own skills (i.e.
536 more overconfidence) to deal with riskier traffic scenarios, such as riding in mixed traffic, or
537 to handle the potential consequences of external sources of risk, such as interaction with other
538 road users. Previous research showed that both drivers and cyclists have shown to adopt risky
539 behaviour as they felt to have control over their behaviour on the road (Castanier et al., 2013;
540 Cristea & Gheorghiu, 2016). In our study, regardless of the direct effect, the consequences of
541 perceived control on the acceptance of riskier traffic scenario are explained through an indirect
542 effect that mediates the relationship.

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

552 In other words, considering the inherent risk of involvement in mixed traffic, this study
553 explores more deeply this relationship, highlighting the role of overconfidence as a possible
554 mediator, predicting the potentially false belief of feeling in control over the bicycle. This could

555 easily lead to a higher involvement in mixed traffic situations and more use of the bicycle,
556 which brings about a higher probability of experiencing a near crash due to reckless conduct,
557 as proposed in Hypothesis 11. Path analysis showed a significant indirect effect of perceived
558 control on near misses throughout the influence of overconfidence, and consequently on
559 bicycle use and avoidance of mixed traffic.

560 In Hypothesis 3, we proposed that cyclists' risk perception regarding the interaction
561 with motorised vehicles would affect their avoidance of mixed traffic, that is, the higher the
562 perceived risk in riding with motorised traffic, the less a person would cycle in those situations,
563 showing different degrees of avoidance behaviour. Path analysis did not show a significant
564 direct effect of risk perception on avoidance behaviour, thus not providing support to
565 hypothesis 3. This result contrasts with previous studies (Chataway et al., 2014; Kaplan &
566 Prato, 2016) which found that fear of traffic (i.e. perceived risk of interaction with cars), was a
567 barrier to cycling especially in urban areas, in particular for non-frequent users and recreational
568 cyclists. Yet, our findings suggest that risk perception regarding the interaction with motorised
569 vehicles cannot explain the adoption of avoidance behaviour by cyclists on its own, but it does
570 so under certain circumstances. These seem to be defined by perceived control, in that only for
571 higher levels of perceived control does risk perception predict the actual avoidance of mixed
572 traffic situations in the hypothesised direction (Hypothesis 3). This is derived from testing
573 Hypothesis 12, which proposed that perceived control would moderate the relationship
574 between risk perception and avoidance of mixed traffic. Despite finding such moderation, the
575 interpretation thereof does not comply with the directions hypothesised. We had foreseen that
576 for higher levels of control, the relationship between risk perception and avoidance would have
577 been weaker due to the higher reliance on one's own skills to face hazardous situations.
578 Nevertheless, our findings make manifest an underlying cause other than expected. A possible
579 interpretation of such effects displayed in Figure 4 and 5 is that only when cyclists perceive

580 they possess enough mastery of the bicycle, they take actions to avoid the risks inherent to
581 mixed traffic as a function of the perceived risk. This does not mean that they do not take any
582 actions regarding the risky situation when they have lower levels of control, it means though
583 that in such conditions it is not a function of perceived risk. As a matter of fact, as previously
584 discussed, regardless of the levels of perceived control, cyclists tend to generally avoid risks
585 as a function of both perceived control and overconfidence. In other words, cyclists with low
586 levels of control and high levels of risk perception will tend to avoid risks because of the low
587 levels of control, but not because risk perception is high. These findings help to understand the
588 interaction between the perceived risk when cycling with motorised vehicles, the perceived
589 control over the bicycle and the avoidance of those traffic situations.

590 **4.1. Implications**

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

605 to the perceived control might backfire on safety outcomes, especially in mixed traffic
606 scenarios.

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

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

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

642 **4.2. Limitations and Future Research**

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

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

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

661 Even if it has been shown that the perception of control over certain situations can act
662 as a spur to execute a given behaviour such as riding a bike (Chaurand & Delhomme, 2013;
663 Cristea & Gheorghiu, 2016; Lois et al., 2015), other bicycle-related factors might directly
664 intervene in the relationship with bicycle use. The literature has revealed a comprehensive set
665 of variables which are relevant to use of the bicycle (Parkin et al., 2008), especially when
666 considering those people that use the bicycle as their main means of transport (Heinen et al.,
667 2010). These factors comprise: socio-economic, psychological, environmental and transport
668 related variables have been shown to influence bicycle use. It was not the intention of this study
669 to discuss on these determinants, nevertheless, to give an extended overview of the main factors
670 influencing bicycle use, future research should focus on how such factors determine the model
671 presented in the present article. Moreover, future research should take into account whether
672 cyclists come from and cycle in urban or rural areas, as well as the amount of motorised
673 transport present in the streets, which plays an important role in cyclists' safety (Heydari et al.,
674 2017).

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

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901

902 APPENDIX A. Items of each subscale.

903

904 Avoidance of mixed traffic (Completely disagree/Completely agree):

- 905 1. When there is no segregated cycle path, I prefer to use other transport modes.
- 906 2. I avoid cycling in mixed traffic during the morning/afternoon peak period.
- 907 3. I avoid cycling in zones where cars pass close to me.

908

909 Risk perception (Never/Always):

- 910 1. I feel unsafe due to the proximity of cars behind me.
- 911 2. I feel unsafe due to the proximity of cars beside me.
- 912 3. I feel unsafe thinking about car doors being opened in my path.

913

914 Perceived control (Completely disagree/ Completely agree):

- 915 1. I have no problem adapting my riding to road surface conditions.
- 916 2. When on my bike, I control my riding no matter how heavy the traffic is.
- 917 3. When on my bike, I control my riding no matter what the weather is like.
- 918 4. When on my bike, I control my riding no matter how fast I'm going.

919

920 Overconfidence (Completely disagree/ Completely agree):

- 921 1. I am sure of myself when riding.
- 922 2. I easily make my way between other vehicles.
- 923 3. I ride better than the average cyclist.
- 924 4. I can drive well even when I'm tired.
- 925 5. I have good reflexes.

926