

# Preferences of European cyclists towards passive and active systems with audio-visual and with handlebar vibration warnings

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## Abstract

In Europe cyclists suffer a disproportionate share of serious injuries and fatalities, and in recent years that disadvantage has been growing. To minimise accidents, different types of collision warning systems have been proposed for motor vehicle drivers. Few studies are available on on-bike systems. The H2020 EU-project XCYCLE developed systems aimed at improving active and passive detection of cyclists informing both drivers and cyclists of hazards at junctions. In the present study, preferences for four different on-bike systems were investigated: 1) passive system without warning; 2) active system with audio-visual warning; 3) active system with handlebar vibration warning; 4) active system with both audio-visual and vibration warning. A sample of 2381 European cyclists from six countries (Italy, Spain, Hungary, Netherlands, Sweden, United Kingdom) answered the online questionnaire. The passive system was the most preferred among the respondents (67.8% would use). Cyclists aged 35-46 showed higher preference for all systems, while those aged 47 and older expressed the lowest preferences for all systems. Participants used to cycle 1-3 day per month exhibit a statistically significant lower intention to buy any type of active on-bike systems.

## Introduction

The number of road accidents is increasing and causing significant losses in many countries, expecting to become the seventh major cause of death by the year 2030 (World Health Organization, 2018). In Europe cyclists suffer a great share of serious injuries and fatalities, partly because they can be considered as vulnerable road users (VRUs) due to a lack of physical protection in the event of a crash with motorised vehicles (Prati et al. 2018). According to the report of the European Road Safety Observatory (ERSO, 2017), while between 2006 and 2015 the number of both overall road fatalities and cyclist fatalities in EU decreased steadily, the number of cyclist fatalities has remained almost unchanged since 2010 and the percentage of cyclists of all road fatalities increased from 7% in 2006 to 8% in 2015. More people in Europe are using the bicycle as an unexpansive, convenient and environmentally safe mode of transport, however it is a fact that cyclists might be more exposed to fatalities (i.e. more exposure, more likelihood to incur in a critical accident).

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As reported by Prati et al. (2017), the type of opponent vehicle is one of the most influential factors impacting the cyclists' crash severity. A situation especially dangerous for cyclists is a conflict with a heavy goods vehicle (HGV) due to their difference in speed and mass (Kröyer, 2015). Previous studies also showed that the increasing levels of van, large automobile, and truck traffic are associated with higher collision risk (Vandenbulcke et al., 2009; Ackery et al., 2011).

In order to improve road safety, in recent years the development and use of intelligent transport systems and advanced assistance systems have received more and more attention (Jamson et al., 2013) whilst vulnerable road users have seldom been addressed as main target (De Angelis et al., 2017). The H2020 EU-project XCYCLE (<http://www.xcycle-h2020.eu>) developed on-bike warning systems to inform truck drivers and/or cyclists (depending on the type of system) about the crash risk at intersections which are considered the third most dangerous scenario for bicycles compared to other modes of transport (ERSO, 2017). The *passive* on-bike system (also called "bike tag") warns the truck driver of the presence of a cyclist in the proximity of the truck. On the other hand, the *active* on-bike system warns the cyclists, alerting them about a dangerous situation. This is done either by means of audio-visual warning (through a device mounted on the handlebar and equipped with a buzzer and a number of LEDs), tactile warning (by means of a vibrating device concealed in the handlebar), or by the combination of these modes (i.e. trimodal warning with acoustic, visual, and tactile warning). The *combined active and passive on-bike system* warns both the cyclist and the truck driver about the collision danger.

While previous studies evaluated preferences and reactions of drivers to different type of warning modes (e.g. Dettman & Bullinger, 2017; Naujoks et al., 2016; Toffetti et al., 2014), to the authors' knowledge, only few studies aimed at exploring cyclists' preferences and reactions to intelligent safety devices with different warning modalities (Engbers et al., 2016; Prati et al., 2018). Particularly, Engbers et al. (2016) evaluated the effects on behaviour, mental effort and acceptance of an electronic rear-view assistance system between two modalities (i.e. visual and haptic) and found less mental effort and significantly more correct decisions regarding a safe left turn when using the rear-view assistant. Similarly, Prati et al. (2018) evaluated users' acceptance of an on-bike system warning about potential collisions with motorised vehicles, as well as its influence on cyclists' behaviour, and found that participants were relatively likely to accept the on-bike system, as well as likely to decrease their speed in case of warning of the on-bike system.

Grounding both on classical socio-psychological theoretical contributions (Ajzen, 1991) and the Technology Acceptance Model (TAM; Davis et al., 1989), it is known that the acceptance of the system has an influence on its future use (Ghazizadeh et al., 2012). Therefore, it is of interest to study the preferences of cyclists in terms of warning modes, especially during the design process of an assistance system (Van der Laan et al., 1997). The aim of the present study was to investigate the willingness to purchase warning modes of regular cyclists, as defined as the likelihood that an individual intends to purchase this product (Dodds et al., 1991). In particular, the preferences of warning modes of regular cyclists in relations with age,

cycling frequency and country of residence were studied. Indeed, previous studies investigating users' preferences of advanced driver-assistance systems (ADAS) have shown the effect of age (Souders et al., 2017) on the evaluation and the acceptance of such road user support systems (e.g. blind spot detection system). Results showed that increased age was associated with a higher valuation for the Active Blind Spot Detection System, even though older adults generally have less familiarity with new technologies (Czaja et al., 2006). To the best of authors' knowledge, the existing literature has rarely been focused on investigating age differences towards on-bike warning systems. Furthermore, since familiarity positively affect the acceptance of a new system (Chang, 2010), a higher willingness to purchase each type of safety device might be expected from regular cyclists who use to cycle every day, and from cyclists who live in countries where cycling level is popular (i.e. the Netherlands and Sweden).

## Method

### *Procedure*

A web-based survey was administered to an online panel of respondents who have agreed in advance to take part in the data collection and resided in six countries (Hungary, Italy, Spain, Sweden, Netherlands, United Kingdom). Since the aim of this study was to target regular cyclists, selection criteria were used for each country. To be included in the study dataset, all respondents had to make on average at least 1 cycle trip per month, at least 50% of them had to be regular cyclists (i.e. make on average more than 2 cycle trips per week), at least 30% had to be female, and at least 10% of the sample had to be aged fifty years or more. Before the survey, the participants watched the video showing the functionality of the examined on-bike systems and the warning modes they employ.

### *Measures*

*Warning mode preference.* As part of a larger set of Stated Preference items, participants were asked by four items "I would not purchase [system type]", with possible options 1 (*yes*) and 2 (*no*). The preference for each warning mode was calculated as percentage of participants' willing to purchase the system. Also, because participants expressed their preference independently for each system type, total percentages reported do not sum up to 100.

*Cycling frequency and Country of residence.* To measure cycling frequency, participants were asked "How many months a year do you normally cycle?". This prompted them to consider their cycling behaviour only during these months and allowed us to account for local geographical differences in terms of weather limitations for bicycle use. To the second item, "In general, during these months, how often do you cycle?", the participants responded using a five-points frequency scale with options 1 (*daily*), 2 (*3 or more days per week*), 3 (*1-2 days per week*), 4 (*1-3 times per month*), and 5 (*less than once per month*). Furthermore, country of residence was considered in the analysis to explore the potential effect of a different national cycling level as defined as the average share of cycling as main mode of

transport (Directorate-General for Communication of the European Commission, 2015) on the willingness to purchase a new on-bike safety system.

*Demographics.* The first part of the questionnaire asked participants about their age, gender, and nationality.

#### *Data analysis*

We created three age bands using tertiles, these were 18-34 years, 35-46 years, and 47 years and more. These categories were created to obtain subsamples with similar sizes. Once the descriptive analysis for demographic data and warning mode preferences had been performed, Friedman's non-parametric ANOVA analysis was carried out to explore significant differences among warning mode preferences. In a second step, a chi-square analysis with Bonferroni correction (i.e. the level of significance was adjusted by dividing the original level of 0.05 by the number of multiple tests performed during each comparison) was conducted to explore any significant differences between age bands, cycling frequencies and national cycling levels.

#### *Participants*

The questionnaire was completed by 2389 respondents. The mean age was 42.75 (SD = 14.34), with the range from 18 to 86 years, with 764 participants with age between 18 and 34 years, 761 participants with age between 35 and 46 years, and 856 participants aged 47 or older. The whole sample consisted of 1210 females (50.6%), 1171 males (49%), and 8 (0.3%) identified themselves as transgender. Concerning the bicycle use, 365 (15.3%) participants used bicycle 1-3 times a month, 707 (29.7%) participants cycled 1-2 days a week, 872 (36.6%) did so 3 or more days a week, and the remaining 437 (18.4%) cycled daily. Out of the whole sample, there were 2381 cyclists in total, i.e. Sweden (n=392), Netherlands (n=395), Hungary (n=399), United Kingdom (n=396), Spain (n=396), and Italy (n=403). In light of these data, all the selection criteria were met.

## **Results**

#### *Warning mode preference*

Overall, results revealed a statistically significant differences on warning mode preference ( $\chi^2_{3, 2381} = 33.27, p < 0.001$ ) with the passive bike tag (without warning) as the most preferred among the respondents (67.8%), followed by active system with audio-visual warning (65.9%), active system with handlebar vibration warning (65.5%) and active system with trimodal warning (62.8%). To explore more in depth the differences between the four type of warning modes, the Wilcoxon signed-rank test showed significant differences among all the warning mode ( $p < .05$ ) except for the preferences between the active system with audio-visual warning system and the active one with handlebar vibration warning ( $Z = -.51, p = .60$ ). The passive tag obtained higher preferences compared to the audio-visual warning ( $Z = -2.06, p = .03$ ), the system with handlebar vibration warning ( $Z = -2.48, p = .01$ ) and the trimodal warning ( $Z = -4.92, p < .001$ ).

Also, the relation between age groups and warning mode preference was examined. The passive system was the most preferred among cyclists from the 35-46 age group (72.0%) and the 18-34 age group (70.5%), whereas in the group aged 47+ the mode preference was lower (61.7%). These differences were statistically significant ( $\chi^2_{1, 2381} = 23.51, p < 0.001$ ). The same mode preference pattern was seen for the active system with tactile warning ( $\chi^2_{1, 2381} = 42.03, p < 0.001$ ), for the active system with audio-visual warning ( $\chi^2_{1, 2381} = 33.93, p < 0.001$ ) and for the active system with trimodal warning mode ( $\chi^2_{1, 2381} = 42.63, p < 0.001$ ). In general, cyclists from the 35-46 age exhibited a statistically significant highest willingness to purchase each type of system ( $p < .01$ ) whereas the older participants represented the group with the statistically significant lower intention ( $p < .001$ ). See Figure 1 for summary.

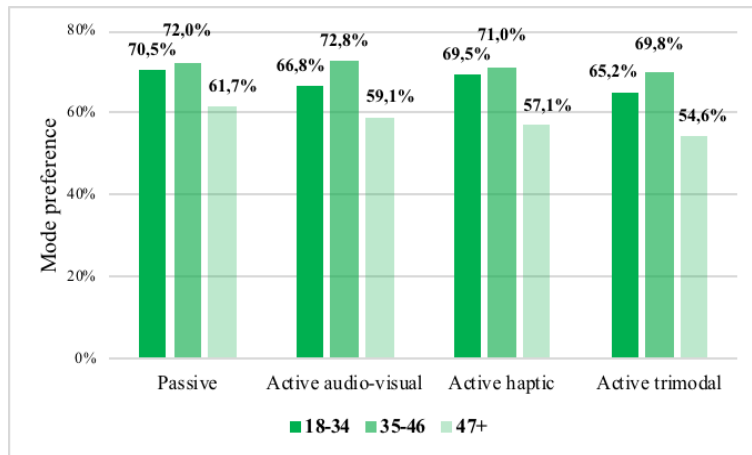


Figure 1. Percentage of participants willing to purchase on-bike systems by age group.

In addition, differences in preferences between groups defined by cycling frequency were examined. In general, there was a positive pattern between cycling frequency and willingness to use each type of on-bike system (i.e. the higher the cycling frequency, the higher the willingness to use the system), except for the trimodal one. The Bonferroni post-hoc correction revealed that those who are used to cycle 1-3 day per month exhibit a statistically significant lower intention to buy any type of active on-bike systems compared to the other groups ( $p < .001$ ). For summary of these results, see Figure 2.

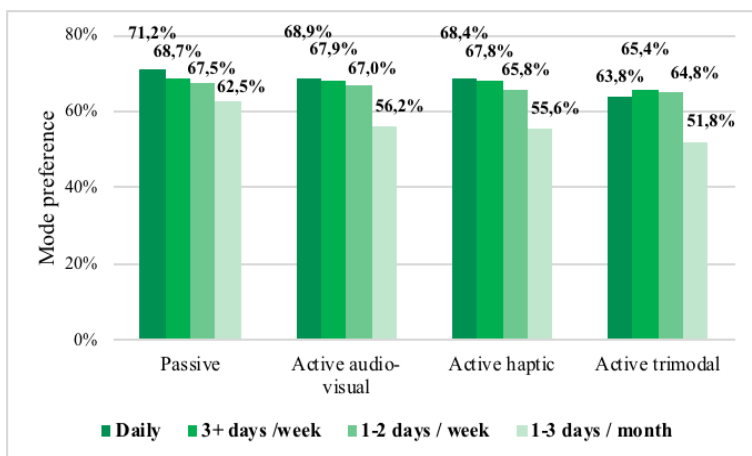


Figure 2. Percentage of participants willing to purchase the on-bike systems by cycling frequency.

Furthermore, cyclists from different national cycling level expressed their preference for each system type. Specifically, compared to the rest of the sample, cyclists from the Netherlands and Sweden (i.e. 36% and 17% respectively) expressed statistically higher preferences for each type of system ( $p < .001$ ). Conversely, cyclists from countries with low national cycling rate (i.e. Italy and Spain, 6% and 3% respectively), exhibited a statistically significant lower willingness to purchase each type of on-bike systems ( $p < .01$ ). Results are summarized in Figure 3.

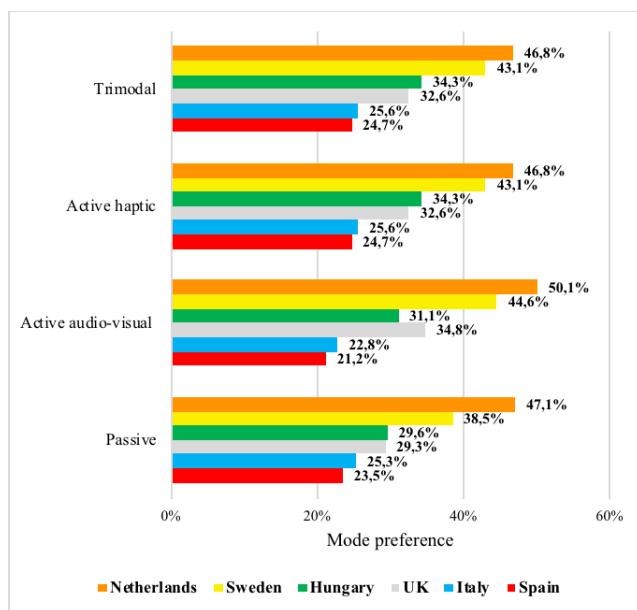


Figure 3. Percentage of participants willing to purchase the on-bike systems by country of residence.

## Discussion

The aim of the present study was to assess regular cyclists' preferences for different warning modes of on-bike systems addressing traffic safety. The results show that the passive tag was overall the most preferred system type. This seems to suggest that the regular cyclist expects being unnoticed by the truck drivers in traffic and therefore is more concerned about being noticed than about seeing the truck potentially crossing her or his trajectory. Therefore, it seems that while being seen is perceived as a priority, warning about a potential collision (mostly audio-visual signal) could be considered as complementary safety measure that has the potential to further improve feelings of safety. Additionally, it emerged how participants exhibited tendentially lower preferences for the haptic and the trimodal warning on-bike systems. Conversely to previous study on car drivers who reacted more positively to the tactile warnings in comparison to an auditory and visual system (Scott & Gray, 2008) or who preferred a combination of warnings designed for shorten their reaction times (Dettmann & Bullinger, 2017; Toffetti et al., 2014), in the present study a lower preference could be due to the fact that tactile warning can be confused with vibrations originating with the contact of the wheels with uneven road surface. Furthermore, the poor willingness to purchase the trimodal warning in comparison with the others seems to indicate that it might perceive as an unnecessarily redundant warning mode.

In general, each type of on-bike system was most preferred by younger adults (i.e. under 47 years), than older adults. A plausible explanation could be that older cyclists may show less willingness to purchase an on-bike system due to lower perceived usefulness, as older adults are willing to overcome barriers such as cost or time to learn only if a presented system has obvious personal benefits (Trübswetter & Bengler, 2013). Other feasible explanation might be older adults' resistance to interact with new and unfamiliar technology (Czaja et al., 2006; Lee, & Coughlin, 2015), or also the fact that older cyclists expected the barriers to be high, possibly because they were not given the opportunity to try the systems in the field.

Differences in preferences between groups defined by cycling frequency were examined. The statistically significant influence of the cycling rate on the general preference seems to suggest that the more one has experience with the bicycle, the more one perceives the potential of the device, being aware of the relative problem of cycling safety showing, in turn, a greater willingness to buy an on-bike system dedicated to increasing comfort and safety. There is evidence that for the acceptance of new technologies familiarity plays a role (Chang, 2010). Indeed, high national cycling level could facilitate the development of a cycling culture, improving overall awareness of cycling safety issues and familiarity with different type of new technological safety device already available on the market. This implies that the possible introduction in the market of the on-bike systems might have more success in countries with higher cycling rates (i.e. the Netherlands, Sweden and Hungary). However, the higher preferences exhibited by cyclists from England, where the average share of cycling as mean mode of transport is poor (i.e. 3% according to the Directorate-General for Communication of the European Commission, 2015) in comparison with cyclists from countries with low cycling level means that other

factors could affect the willingness to purchase an on-bike safety device such as the level of cycling infrastructure as well as accessibility and national cycling safety awareness. Further studies are encouraged to understand the mechanisms explaining these relationships. Within this perspective, the implementation of a technology that can be accepted by different groups of cyclists from different national cycling level should be encouraged to further support designers and decision makers in the field of mobility and cycling safety measures

This study has limitations which should be recognised. Firstly, the applicability to other segments of the regular cyclist population was limited due to the requirement for e-mail and Internet access. Furthermore, the extension of the findings is limited because the study population is self-selective (i.e. online panel). Finally, the survey data are based on self-reported information and are open to recall bias and reporting errors (Stone et al., 2002). Finally, participants were asked to evaluate the on-bike systems without having experienced them, which may have influenced the results due to a lack of understanding. Further investigations could consider virtual and augmented reality to improve the quality of the experience, but still make it more affordable than real prototyping (Lawson et al., 2016).

### Conclusions

The preference of warning modes for on-bike collision avoidance systems was explored in a sample of regular cyclists. The study showed that during the design process of an on-bike assistance system, based on a user centred approach, age bands, cycling frequency and national cycling level could be significant dimensions to consider, in the perspective of bringing the system to the market with a higher probability of acceptance by users.

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