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Research article

Better safe than sorry – Understanding the attitude and habits of drivers can help mitigating animal-vehicle collisions

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ABSTRACT

The rapidly growing global road networks put serious pressures on terrestrial ecosystems and increase the number and severity of human-wildlife conflicts, which in most cases manifest in animal-vehicle collisions (AVCs). AVCs pose serious problems both for biodiversity conservation and traffic safety: each year, millions of vertebrates are roadkilled globally and the related economic damage is also substantial. For a comprehensive understanding of factors influencing AVC it is essential to explore the human factor, that is, the habits and attitude of drivers; however, to date, comprehensive surveys are lacking on this topic. Here we addressed this knowledge gap and surveyed the habits of drivers and their experience and attitude towards AVCs by a comprehensive questionnaire covering a large geographical area and involving a large number of respondents (1942 completed questionnaires). We aimed to reveal how driving habits affect the chance of AVC, and explored the attitude of the drivers regarding AVC. We found that the number of lifetime AVC cases was higher for male drivers, for those who drove longer distances per year, had more driven years, used country roads or drove large vehicles. Our results showed that almost half of the drivers surveyed had experienced at least one AVC in their lifetime. Drivers' attitudes towards the importance of nature conservation or traffic safety in the aspect of AVC, and fear of collision showed a significant correlation with experienced AVC cases. Drivers' opinions indicated that the most trusted and desired AVC prevention measures were physical objects such as fences and wildlife crossings. Our research provides guidelines for developing targeted initiatives in the future to increase awareness about the significance of AVC and target those drivers who are most vulnerable to AVC.

1. Introduction

Transportation is one of the most important pillars of economy and is considered also an essential element of our everyday lives. In the last decades, the extension of road networks and the number of vehicles increased considerably all around the world (Ibisch et al., 2016; van der Ree et al., 2015). While in 1976 the number of registered vehicles was only 342 million worldwide, which number doubled by 1996 and in 2016 it reached 1.32 billion. This suggests that the number of vehicles in traffic doubles every twenty years (Cars Guide, 2022). Road networks are one the main sources of global habitat fragmentation. Ibisch et al. (2016) showed that 80% of the terrestrial surface was fragmented to patches smaller than 1 km^2 in which roads have a crucial role. This means that for animal species with large mobility and large home ranges, it is inevitable to regularly cross roads. All these put serious pressure on terrestrial ecosystems and result in increasing frequency and severity of human-wildlife conflicts, which in most cases manifest in animal-vehicle collisions (AVC) (Coffin, 2007). Hill et al. (2019) found that the third largest human-induced mortality cause for vertebrates was AVC. At least 400 million vertebrates are roadkilled in the world per year (Schwartz et al., 2020). Based on the study by Grilo et al. (2020), the average number of roadkilled birds and mammals is estimated over 200 million individuals per year along the European road networks.

Recent reports showed that the frequency of AVC events is rapidly increasing. For example, the number of reported accidents with large-bodied ungulates has increased by 36% between 2003 and 2015 in

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Sweden (Gren and Jägerbrand, 2019), became almost tenfold larger in Lithuania between 2002 and 2017 (Kučas and Balčiauskas, 2020), and doubled in Poland between 2001 and 2010 (Borowik et al., 2021). Although it should be mentioned that these numbers could be influenced by the methodology of the survey (Flux et al., 2022). As collisions with large-bodied mammals pose remarkable traffic safety risks, there is far more accurate information on these incidents compared to AVC involving smaller-bodied animals (Marcoux and Riley, 2010). For AVC involving smaller animals, mostly estimations are available that upscale data from case studies and regional roadkill surveys. A high proportion of roadkill events remain undocumented because they are related to small-bodied taxa, such as many representatives of amphibians, reptiles, birds and mammals, and even invertebrates (Martin et al., 2018) which mostly do not cause damage in the vehicle and drivers hardly even notice if they hit a small animal (Bíl et al., 2020).

AVCs represent a serious nature conservation problem especially in protected areas. These areas often receive many visitors and also experience an intensive level of traffic. This can pose serious conservation problems, because even in protected areas animals are generally protected against AVC only in short road sections (Garriga et al., 2012; Saranholi et al., 2016; Collinson et al., 2019). The proportion of roadkill-affected vertebrate classes varies among the studies. According to a survey in Biebrza National Park, Poland, 90.7% of roadkilled individuals were amphibians, mainly frogs and toads (Gryz and Krauze, 2008). In a protected area of Cerrado, Brazil, the largest proportion of roadkilled animals were constituted by mammals (54%) (Saranholi et al., 2016). In some cases, roadkill is a high-risk mortality factor for the populations of vulnerable species. According to the review of Borza et al. (2021), the proportion of protected vertebrate species exceeds 80% of the roadkilled taxa in Hungary, suggesting that the damage for nature conservation is substantial. Roadkill seriously threatens the populations of endangered mammals, such as Iberian lynx (*Lynx pardinus*), the Amur tiger (*Panthera tigris altaica*) the Lion-tailed macaque (*Macaca silenus*), Sloth bear (*Melursus ursinus*), the Oncilla (*Leopardus tigrinus*) the Wild yak (*Bos mutus*), and the Ryukyu long-furred rat (*Diplothrix legata*) (Grilo et al., 2021; Miyamoto et al., 2021). In the case of some species, the observed roadkill rates may lead to increased risk of extinction in the near future.

Besides endangering wildlife, AVCs can cause damage to property. In addition to the fact that AVCs can result in a large cost of the economic damage of car owners, the financial loss of insurance companies can also be quite high (Mayer et al., 2021). In the vast majority of cases, large-bodied ungulates are involved in traffic accidents leading to a considerable financial loss. In Sweden, the estimated annual cost of AVC is amounted to 406 million USD, which is mainly caused by deer species (*Cervus* spp.) and wild boar (*Sus scrofa*) (Ascensão et al., 2021). In California, the cost of economic damage was 76 million USD in 2018 (Ascensão et al., 2021). Occasionally, personal injury may also occur, and in certain cases AVC can also have a fatal outcome for the travellers (Seiler, 2005).

Reducing AVC frequency and severity by mitigation measures is crucial both for the wildlife conservation and for the traffic safety (Coffin, 2007; Tryjanowski et al., 2021). For road managers, deciding on what mitigation method to use is often challenging. It is crucial to consider both the relative effectiveness of measures in reducing AVC, and the related costs (Rytwinski et al., 2016). Implementing a single measure may not be enough to prevent AVCs, and it is also crucial to consider the drivers' recommendations on what they prefer (Kioko et al., 2015; Rytwinski et al., 2016). For instance, implementing a rule or speed limit will be ineffective if people choose not to observe them due to inconvenience or increased travel time (Kioko et al., 2015; Collinson et al., 2019; Druta and Alden, 2020). In order to reduce the AVC rate, we also need to understand the causes of collisions. Landscape ecological analyses are used for predicting AVC hotspots based on the landscape composition, and the traits and movements of animals (Valerio et al., 2023). The place for warning signs is usually chosen this way (Tryjanowski et al., 2021). However, for a comprehensive understanding of factors influencing AVC it is also essential to explore the human factor, that is, the habits and attitude of drivers.

For obtaining valuable scientific information from drivers, questionnaire-based research can be an effective tool. Beckmann and Shine (2012) surveyed 1241 people in Australia about observation of roadkilled amphibians and reptiles and/or about intentionality of running over one. They found that according to the drivers' responses, 25% of them had negative feelings about these taxa and run over toads intentionally, however a related field experiment did not support this finding. Kioko et al. (2015) interviewed 60 drivers in Tanzania about their attitude, knowledge and level of awareness of AVCs. The respondents were neutral about AVCs, and they thought it is an accidental event that cannot be avoided. This result highlighted the importance of education of road users towards driving responsibility. Marcoux and Riley (2010) made interviews involving 30 drivers in the USA about their attitude and knowledge about AVCs. They found that the majority of drivers consider AVC to be a serious problem. The interviewed drivers were willing to change their driving habits to a certain extent in order to reduce the risk of collisions. Driving habit of a person is a characteristic that develops over time from the interaction of a sort of variables, for example age, gender, experience and personal judgment. All of this influence several attributes, like patience, driving ability and style, the used road types, all of which affect the probability of a collision (Sagberg et al., 2015). Although questionnaires can be a valuable tool for gaining a deeper understanding of a topic, but it is crucial to recognize the limitations and biases inherent in this method. To ensure the best results, it is important to consider various factors when designing a questionnaire, for example sufficient sample size, simplicity, assessing accuracy of the data (for more detail see White et al., 2005).

In this study, our aim was to survey the habits of drivers together with their experience and attitude towards AVCs by a comprehensive questionnaire covering a large geographical area and involving a large number of respondents. We aimed to reveal how driving habits affect the chance of AVC, and we explored the attitude of the drivers regarding AVC.

Our main questions were:

(i) Which are the animal groups that are the most affected by AVCs? (ii) Do drivers' attributes (i.e., driven years, driven kilometre per year, driving style, gender, vehicle type, used road types) influence the possibility of AVCs? (iii) Is there any correlation between drivers' attributes and their attitude towards nature conservation, traffic safety and fear of AVC? (iv) What kind of defensive measures do drivers consider useful to prevent AVCs?

Surveys have already been made to reveal the effect of human factor in AVCs (see Marcoux and Riley, 2010; Beckmann and Shine, 2012; Kioko et al., 2015), but up to our knowledge, such large-scale and comprehensive survey like ours has not been carried out so far.

2. Material and methods

2.1. Questionnaire design

The structure of the online questionnaire, the asked questions and type of the collected data are explained in Table 1. We also asked further questions related to frequency of AVCs with certain animal groups, personal experiences (injury and damage of property experienced in AVCs) and an open-ended question about personal opinion about prevention measures.

The questionnaire was designed using Google Forms in Hungarian language. We aimed to reach a wide range of the society, so for propagating the questionnaire we used several different Hungarian media channels e.g., social media, websites, broadcasts, etc. The collection of responses lasted for one year, from January 2021 till January 2022. We did not ask for any sensitive information or for personal data based on which any participants could have been identifiable.

Table 1
The structure of the questionnaire: the questions, their relevance for the study and type of the collected data.

Question	Type of the collected data	Variable name and type	Indicates
What gender do you consider yourself to be?	Binary scale (male; female)	Gender (explanatory variable)	General driving attitude involving risk-taking
How many years have you been actively driving?	Continuous scale	Driven years (explanatory variable)	Level of driving experience
Which one describes best your driving style?	Ordinal scale (slow; normal; dynamic)	Driving style (explanatory variable)	Chances of detecting and avoiding AVC
What kind of vehicle do you drive the most?	Ordinal scale (motorbike; car; van/bus/truck)	Vehicle type (explanatory variable)	Chance of avoiding AVC due to the technical attributes of the vehicle (i.e., front surface, manoeuvrability, breaking distance)
How many kilometres do you drive domestically with this vehicle on average per year?	Ordinal scale (0–5000; 5000–10,000; 10,000–25,000; 25,000–50,000; 50,000+)	Driven kilometre per year (explanatory variable)	Level of driving experience and by increasing distance the chance for the potential AVC increases
How often do you use the different types of roads?	Ordinal scale for each road type (city; county road/ main road; expressway/ motorway)	Road type (explanatory variable)	Chance of potential AVC
How often do you observe roadkilled animal?	Ordinal scale (daily; many times per week; few times per week; many times per month; few times per month; many times per year; few times per year; never)	Observation of roadkilled animal (explanatory variable)	Encountering the consequences of roadkill
Have you ever had AVC in your lifetime?	Binary scale (yes; no)	Animal hit (response variable)	Direct involvement in AVC with any kind of vertebrate
Have you ever had AVC with a large mammal?	Binary scale (yes; no)	AVC with large mammal (explanatory variable)	Direct involvement in AVC with a large mammal
How important do you think our research is from a nature conservation point of view?	Ordinal scale (not important; less important; neutral; important, very important)	Importance of nature conservation (explanatory variable)	Personal attitude on nature conservation
How important do you think our research is from a traffic safety point of view?	Ordinal scale (not important; less important; neutral; important, very important)	Importance of traffic safety (explanatory variable)	Personal attitude on traffic safety
How much are you afraid of AVC?	Ordinal scale (five-grade scale, where 1 was no fear, while 5 was serious concern)	Fear from AVC (explanatory variable)	Proxy for personal opinion about fear of collision

2.2. Study area

We collected data from Hungarian drivers focusing on AVC events occurred in Hungary. Hungary is located in Central Europe, with an area of 93,030 square kilometres. The length of the public road network is 32,521 km, of which the length of the motorways and expressways amounted to 2389 km and the main roads and county roads was 30,132 km, respectively. The number of vehicles used in the roads of the country in 2021 was 4,885,589, of which 4,020,159 were cars. The number of vehicles in 2020 were 403 per 1000 people, which is above the global average (139 per 1000 people) and below the EU's average (560 per 1000 people) (Hungarian Central Statistical Office, 2023).

2.3. Statistical analysis

For the statistical analysis motorway and expressway were merged as "first-class road", as well as the main roads and county roads were merged as "second-class road" because of their similar role and characteristics. We also merged van, bus, and truck as "large vehicle" for same reasons.

To analyse the relationships between the 'animal hit' as binary response variable (yes or no) and predictors (drivers' attributes), we first formulated a generalised logistic regression model fitted on the 'animal hit' binary response as a function of the log-transformed number of driven years, vehicle type, driven kilometres per year, driving style, road type and gender of the driver, considering binomial error distribution with logit link, which we considered as the full model. In the following step, to provide robust assessments of the predictors, we conducted model selection based on Akaike Information Criteria corrected for small sample sizes (AICc, Burnham and Anderson, 2002). Accordingly, we generated all possible model combinations of the predictors (drivers' attributes) and computed parameter estimates and related p-values applying approximations by z-statistics, across i) the whole set of candidate models and ii) the subset of models containing the particular predictors.

To investigate the associations between the drivers' attributes and drivers' attitudes, we considered the answers questions related to i) importance of conservation; ii) importance of traffic safety and iii) fear of collision as response variables, as a function of 'hit large mammal' as binary variable (yes or no) and the drivers' attributes considered in the previous analysis, fitting linear regressions for all three cases. For each of the three full models, we conducted model selection as described in the previous section.

To estimate relationships among driving predictors, we calculated Variance Inflation Factors (VIF) across all full models considered. Because VIF scores were lower than 1.6 for each predictor (multicollinearity being negligible) we considered all explanatory variables for the statistical analyses.

We used the 'regclass' package (Petrie, 2020) for calculating VIF, and the 'MuMIn' package (Barton, 2011) for model selection procedures. All statistical analyses were carried out in the R statistical programming environment (R Core Team, 2022).

3. Results

3.1. Respondents' attributes and roadkill cases

We received responses from a total of 2123 people, of which 1942 respondents were drivers. For the analysis we used only the data received from drivers. The age of drivers ranged between 19 and 89 years, which corresponds to the average age of active drivers in Hungary (average in our study 42.8 years, average in Hungary 42.9 years) (Hungarian Central Statistical Office, 2023). The proportion of male and female respondents was 65.5% and 34.5%, respectively. Driven years ranged from 0.5 to 60 years. 92.8% of the drivers used car for transportation, and the largest proportion (39.3%) drove between 10,000 and 25,000 km per year. Percentage proportions of driving style categories were 25.5% for slow, 38.7% for normal, 35.8% for dynamic driving style, respectively.

45.8% of the respondents were involved in AVCs; 8.0% reported one case, while 37.8% reported more cases during their lifetime. In 54.0% of the AVC cases a certain level damage occurred in the vehicle, which means that every fourth driver was affected. The total amount of property damage reported by the respondents exceeded 150 million HUF (approx. 400,000 USD). On average the damage of property was 300,000 HUF (approx. 800 USD) per AVC case. 1.8% of AVC cases ended in traffic accident (e.g., driving into a ditch, hitting a tree or another car), and the half of the accidents resulted in personal injuries.

3.2. Reported roadkilled taxa

The largest number of AVCs were reported related with small-sized birds; 28.2% of respondents had one or more collision with this animal group. In contrast, the lowest proportions of AVC cases were reported for amphibians and reptiles (15.8%), medium- and large-sized birds (16.3% and 12.6%) and small mammals (16.1%). 19.8% of the respondents had collision with a medium-sized mammal, while 21.7% with a large-bodied mammal. In case of AVC with large-bodied mammal, the drivers reported collision with roe deer (*Capreolus capreolus*) most often. The proportion of roadkilled domestic pets (cat or dog) were relatively high, 23.9% of respondents had one or more collisions with them. 22.1% of the drivers reported that they do not know if they had AVC with an amphibian or a reptile. 15.8% of the drivers reported AVC with small mammals. 4.8% of drivers reported that they do not know if they had AVC with a bird of any size. The lowest proportion of uncertain AVC cases was reported for medium and large-bodied mammals (2.5% and 1.9%) and for pets (2.3%) (Fig. 1).

3.3. Factors influencing occurrence of AVC

The occurrence of AVC cases was higher in the case of drivers who drive more kilometres per year, also for those who had more driven years (Table 2). Drivers who drive more often on second-class roads more likely had AVC than drivers who preferred the first-class roads or drive mostly in the cities. Male drivers were involved in AVCs more frequently than female drivers. Drivers of large vehicles hit significantly more animals compared to drivers of cars or motorbikes. We did not find any significant correlation between driving style and the frequency of AVC cases (Table S1).

3.4. Drivers attitude towards nature conservation and traffic safety

Those drivers who observed roadkilled animals more often along the roads considered nature conservation more important. There was significant difference between the attitude of genders. We found that male drivers considered nature conservation less important than female drivers. Drivers who drove more dynamically and used second-class roads more often considered nature conservation less important (Table S2).

Drivers who described themselves as dynamic drivers and used first-class roads more often considered the traffic safety to be less important. Similar result was observed in the case of male drivers. In contrast, drivers who observed more roadkilled animals and had an AVC with a large mammal in their lifetime considered traffic safety to be important. We had similar result with drivers who use city roads more frequently (Table S3).

Those drivers who showed significantly less fear of AVC drive more dynamically, have more driven years and use first-class roads. Male drivers showed less fear of AVC. Those drivers showed more intense fear of AVC who had AVC with a large mammal in their lifetime, used mainly second-class roads, and observed roadkilled animals more often (Table S4).

Table 2
Personal opinion of drivers about effective AVC prevention measures.

Prevention or mitigation measure	Number and proportion of recommendations
Physical structures (fence, wildlife crossing)	289 (30.6%)
Game management, more responsibility on hunter services	152 (16.1%)
Raising awareness for AVC from both traffic safety and conservation perspectives, warning posters road signs and signals	157 (16.6%)
Technological innovations	117 (12.4%)
Developing driving education	86 (9.1%)
Road maintenance, keep the roadsides clear	70 (7.4%)
Introduction and enforcement of speed limits	55 (5.8%)
Traffic reduction	9 (1.0%)
Scientific research	7 (0.7%)
Manage stray animals	6 (0.6%)

3.5. Opinion on roadkill prevention

A total of 797 drivers provided one or more personal recommendations on what they believe to be effective measures to prevent AVCs (Table 2). The drivers mentioned both practical interventions and theoretical concepts in their answers.

4. Discussion

In our questionnaire study involving 1942 respondents, we surveyed the experiences and attitude of novice and experienced drivers

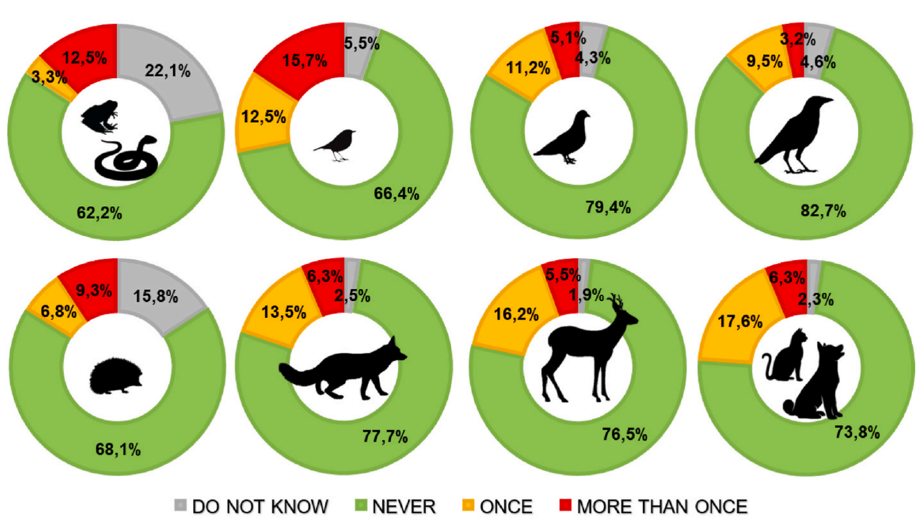

Fig. 1. Proportion of lifetime AVC cases for different animal groups.

regarding AVCs. We found that AVC is a widespread problem that affects a large proportion of people participating in traffic. Our results showed that almost half of the drivers surveyed experienced at least one AVC in their lifetime. We found significant correlations between drivers' attributes and attitudes and occurrence of AVC cases. Drivers' attitudes towards the importance of nature conservation or traffic safety in the aspect of AVC, and also fear of collision with animals showed a significant correlation with formerly experienced AVC events. Besides, AVC can cause remarkable damage of property or injury to drivers, it is an urgent problem for nature conservation as well.

4.1. Reported roadkilled taxa

Small-sized birds were the most often reported roadkilled animal group in our survey. This is in line with the result of field surveys from other countries (Grilo et al., 2020; Dhiab and Selmi, 2021). Interestingly, the results of a review study from Hungary found that amphibians were roadkilled in the largest numbers (Borza et al., 2021). Kioko et al. (2015) also found such a contradiction, they showed that roadkill data derived from drivers and collected in the field suggested different taxa as most affected one. The possible explanation for this phenomenon is that monitoring of amphibians is generally well-organised and special attention is paid on road surveys to reveal mass roadkill events (Borza et al., 2021). For birds there is no such system, and it is also harder to find the individual carcasses because they often drift away due to the collision. Also, during driving, the detectability of certain taxa – in our case birds and amphibians – may be remarkably different. This was reflected in the very different level of uncertainty of AVC cases with amphibians and reptiles and birds. Bird species often cross the roads at potential collision heights, which often means eye-level, and are active during daytime (Betleja et al., 2020). In addition, there is a "knock" sound effect when a bird is hit, so they are easy to notice. While amphibians moving in the ground-level or sit motionless on the ground, rather active during the night and often in such weather, like rain, when visibility is poor, all of which make difficult to spot them (Elzanowski et al., 2009). Furthermore, amphibians generally do not pose a considerable traffic safety risk, so drivers do not try to swerve running over them (Crawford and Andrews, 2016), which probably makes the encounter less memorable.

In contrast, stray and free-roaming domesticated animals cause serious problems worldwide, and pose serious traffic safety risk. According to a case study in India as many as 69% of road traffic accidents were caused by stray dogs (Mohanty et al., 2021). In Tunisia, 16% of roadkilled animals are semi-feral animals (Dhiab and Selmi, 2021), which is similar to our results (23.9%). Stray animals often roam in roads inside and outside of urban areas and feed on dead, formerly hit animals found on the road, which makes them susceptible to collision and explain the high roadkill rates (Canal et al., 2018; Dhiab and Selmi, 2021). Intentional roadkill may also exist for stray animals (Beckmann and Shine, 2012; de Resende Assis et al., 2020). Bassett et al. (2020) found that many people do not like free-roaming cats because they represent a threat to wildlife so may run over them intentionally or at least do not try to swerve the collision, which increases the number of AVCs. In our questionnaire we found evidence for this; a respondent reported the intentional roadkill of more than one hundred cats in his lifetime. It is also possible that due to emotional bonding, people remember better to run over a cat or dog (Crawford and Andrews, 2016), so the reported numbers are higher and reflect more precisely the real number of AVC cases.

We detected a high number of reported AVCs with large mammals. The most affected species was roe deer. There could be multiple reasons for the high number of cases. First of all, roe deer is a large-bodied animal, and it is almost impossible not to notice the collision (Markolt et al., 2012) not so with many smaller animals. Thus, the reported numbers likely equal to the real AVC cases. Also, roe deer occurs in almost every terrestrial habitat in Hungary where it is an abundant species (Tóth et al., 2010). Roe deer has large home range (mean monthly home range in Hungary is about 430 ha, but can reach 1630 ha) so its habitat is most likely fragmented by roads (Tóth et al., 2010). Although the study of Coulon et al. (2008) shows that roe deer avoid roads, yet it seems that in many instances it is inevitable for the species to cross the road. As a consequence, roe deer is often affected by AVCs in Hungary and in several other countries too, and can comprise even more than half of all registered roadkilled wild mammals (Cserkész et al., 2013; Mrtka and Borkovcová, 2013; Kučas and Balčiauskas, 2020; Mayer et al., 2021). Due to large body size, collision with deer species, including roe deer, often cause large economic damage (Sullivan, 2011; Mrtka and Borkovcová, 2013; Kučas and Balčiauskas, 2020), which was reported by a quarter of our respondents. AVC with large mammals also cause injuries or fatalities of many people (Seiler, 2005; Sullivan, 2011; Vanlaar et al., 2019). We did not register the latter case; however, Cserkész et al. (2013) noted that one to two AVCs lead to the death of the driver in every year on the Hungarian first-class roads.

4.2. Factors influencing occurrence of AVC

We found that the chance of AVC increases markedly with more driven years and more driven kilometres per year, that cannot be counterbalanced by the experience gained during years. The latter finding is in accordance with the finding of a Canadian research that found that many experienced drivers are often unaware of the safest solution to avoid serious consequences of AVC, i.e., to slow down and steer straight. Not even drivers who have appropriate knowledge, in practice, do not act this way in an AVC situation and rather try to swerve the collision (Vanlaar et al., 2019).

To decrease the possibility of fatal AVCs, in most sections along the first-class roads wildlife protection fences are built. Second-class roads generally do not have this kind of defensive investment, which is well reflected in the experienced high AVC rates on them.

Gender of drivers was a good predictor of AVC occurrences. The review of Sagberg et al. (2015) identifies several differences between male and female drivers. They showed that males drive slightly faster in certain road types, are generally more offensive, and adopt a riskier manner of driving, explained by innate biological and sociocultural factors. Female drivers generally follow traffic rules more than males (Laapotti et al., 2003). These can be connected with our findings, i.e., the more frequent AVC rate of male drivers. Despite the difference in number of AVCs between male and female drivers there were no direct patterns suggesting that driving style can influence the possibility of AVC. The reason for this is that driving style is probably not the only characteristics of genders that influence AVC rates. Also, the heterogeneity of driving style within gender may have blurred the difference in our case (Sagberg et al., 2015).

We found a proportionally higher rate of AVC occurrences in the case of large vehicles, which also implies, that even the most experienced professional drivers cannot avoid AVC. On the other hand, a larger vehicle more likely collides with animals because of the larger front surface and the manoeuvring limits. As truck drivers spend a lot of time driving, they may run over objects as a way to 'self-entertainment' (Secco et al., 2014), and because of some misinformation and negative public attitudes towards certain animal species, e.g., snakes (de Resende Assis et al., 2020), although this was not investigated by our research.

4.3. Attitude towards nature conservation and traffic safety aspects of AVC

Women's concern for wildlife is based mostly on emotional bounds to individual animals, and they generally express stronger support towards conservation issues than men (Czech et al., 2001). Our results also supported that nature conservation aspect of AVC is more important to female drivers. Observing roadkilled animals may further sensitize people about conservation issues regardless of their gender. According to the survey of Crawford and Andrews (2016) the respondents who showed concern for wildlife were more likely to be upset when hit an animal, which is likely attributable to strong emotional affection toward individual animals or frequent exposure to the species they roadkilled through natural observations, media or educational programs. People's attitude toward nature conservation fundamentally determines their driving related choice of action and behaviour (Czech et al., 2001; Crawford and Andrews, 2016). This can explain our result that drivers who were less concerned about nature conservation drive more dynamically, probably disregarding if run over an animal and not willing to do active measures to reduce the risk of an AVC. It should be noted that even those who are concerned about AVCs may still be passive, as they believe that these incidents are part of the transportation and cannot be prevented (Marcoux and Riley, 2010; Kioko et al., 2015).

People's attitudes towards AVCs are shaped by their personal experiences and backgrounds (Sagberg et al., 2015). Frequent sightings of roadkill can heighten awareness of the risks associated with AVCs and emphasize the need for prevention measures and road safety. Likewise, individuals who have suffered an AVC or frequently drive on second-class roads where animal crossings are prevalent are likely to prioritize traffic safety. Respondents who frequently drive in the cities tend to view traffic safety as a crucial issue. This is probably because urban populations generally have a higher concern for traffic safety due to the higher number of accidents that occur in the city centres, causing people to be more afraid of such cases (von Wirth et al., 2015). Studies have shown that male drivers exhibit negative attitudes toward traffic rules and safe driving (Laapotti et al., 2003), which can explain the less care for the traffic safety aspect of AVC of male drivers.

Due to the fences lining the roads, animals are rarely seen on first-class roads which increased drivers' sense of security and made them feel less exposed to AVC. This perceived security and the relatively low number of AVCs along first-class roads made some drivers to overlook the importance of protective measures against AVC. Although this is partly a misconception, as even the fences can't guarantee complete protection from AVCs (Cserkész et al., 2013; Nowakowski et al., 2022). In fact, as Cserkész et al. (2013) noted, 5% of traffic accidents on Hungarian first-class roads are caused by AVCs, emphasizing the need for extra precautions and the importance of additional protective measures along roads.

More driven years gave people a false sense of security. With more experience, they may drive at faster speeds and feel enabled to handle unexpected driving situations, such as AVC. This overconfidence could lead to a decreased emphasis on traffic safety and a misleading belief that their experience alone can prevent accidents. The reason why men are less apprehensive about AVCs can be traced back to biological variations, such as hormonal differences and the desire to meet societal expectations, e.g., to be brave (Sagberg et al., 2015). When drivers see wildlife crossing the road or roadkilled animals, it can be distracting and cause them to feel unsafe about the road ahead. Additionally, if a driver had a previous collision with a large mammal, such as a deer, it can increase their anxiety and fear of having another similar encounter. This can lead to decreased concentration, slower driving speeds, and a greater likelihood of making mistakes on the road, although we did not study these changes.

4.4. Opinion on AVC prevention

The prevalence of physical mitigation measures, i.e., fences and wildlife crossings likely stem from the fact that these are convenient solutions and do not require any sacrifices from the drivers' side. Our results showed that these measures increased the confidence of the drivers, however they were not fully aware the limitations of these (see also Cserkész et al., 2013; Nowakowski et al., 2022). A fence installation on its own can decrease the risk of AVCs with large mammals by 54%, and with the addition of a wildlife crossing, this risk can be reduced by as much as 83% (Rytwinski et al., 2016). Ascensão et al. (2021) conducted a cost-benefit analysis in Brazil to determine the return on investment for road fencing projects. The results showed that regularly the investment pays off within 16–40 years for full road fencing, and within 9–25 years in areas with high AVC rates. Considering these factors, fences and crossings can certainly serve as a viable partial solution; however, for adequate protection against larger animals further measures are necessary. Game management, i.e., reduction of population size of large game species, which has been recommended by several drivers in our survey, might be a useful addition, as data shows that large-bodied game species pose the greatest problem and are responsible for the most incidents (Mrtka and Borkovcová, 2013; Kučas and Balčiauskas, 2020; Mayer et al., 2021). The studies mentioned previously only consider traffic safety. From the perspective of wildlife conservation, fences and crossing structures may not effectively address the problem in certain situations, as only a few species benefit from it, but the roadkill rate for many other species remain steady (Bager and Fontoura, 2013). Also if the use of fences is to be expanded, it is important to be mindful of potential negative consequences, such as habitat fragmentation.

The respondents in our survey considered increasing of awareness about AVC through various channels (e.g., advertisements, posters and signs along roads, environmental education) an important measure that can effectively reduce the occurrence of incidents. Collinson et al. (2019) found that warning signs can only be helpful if drivers respond appropriately to the signs and follow the indications, that emphasize the importance of education and increasing sensitivity of drivers towards AVC avoidance. In addition, it is crucial to educate drivers on how to handle AVC situations, as suggested by multiple drivers. However, this topic is largely neglected in driver education programs (Lunney, 2013).

Technological innovations were also among the most frequently suggested prevention and mitigation measures by the respondents of our survey. Thanks to the rapid development of science, many innovative AVC prevention systems were developed and are being tested around the world. These systems are designed to recognize and alert drivers of any animals standing on or walking onto the road. Despite their efficacy, these systems have certain limitations. For instance, they are costly and site-specific (it can only be installed in certain locations) (Fox et al., 2018; Druta and Alden, 2020), or only capable to predict collisions in time up to a limited speed (Sharma and Shah, 2016), so complementary measures are needed to prevent collisions. Given the general desire for preventive techniques, there is a demand for a cost-effective solution that can be utilized anywhere, e.g., a system that can be integrated into any vehicle, making it readily accessible to a broader audience.

Although road managers would also benefit from evidence-based information about the effects of speed limits, there is limited research available that assesses the efficiency of this preventive measure (Rytwinski et al., 2016). As Druta and Alden (2020) showed, even a prepared driver may still hit an animal if they are driving too fast. Whereas driving at a slower speed can help reduce the likelihood of such incidents because drivers become able to detect and avoid animals even within a short detection distance. However, in today's fast-paced society, this solution is likely not the most desirable for most people, leading to limited suggestions received for it.

Management of roadside vegetation was suggested by 7% of the respondents. Maintaining short vegetation can basically reduce the chance of roadkill by eliminating the animals' hiding and feeding places, so that certain species occur in smaller numbers directly along the road. Also it is easier to notice if something is moving towards the road in the short lawn. Although this preventive measure should be considered from a nature conservation point of view, because roadside verges are important habitats and have remarkable role in maintaining biodiversity (Auffret and Lindgren, 2020).

There were other prevention and mitigation measures that were suggested by a small number of respondents. Stray animals and free-roaming large domesticated animals are not as much of a problem in terms of AVCs in the studied region compared to places like India

(Mohanty et al., 2021), which explains why only a few drivers have put forward suggestions to reduce their numbers. A few drivers also suggested to do more scientific research in the topic. With growing public concern over AVC, there are several opportunities for drivers to participate in the collection of data through citizen science (Vercayie and Herremans, 2015; Hsu and Lin, 2021). This provides opportunity not only for documenting instances of roadkill, but also identifying the impact of human attributes and attitudes on the occurrence of AVC.

5. Conclusions and outlook

Human-wildlife conflict situations can be considered an actual pressing issue both from social and nature conservation points of view. The importance of the topic and the social sensitivity is clearly shown by the large number of respondents interested in completing the questionnaire. Our results clearly show that AVC is a widely prevalent issue that affects a large number of drivers. The occurrence of AVC is influenced by several factors, for example the surrounding landscape, abundance of wildlife, but here we showed that the human factor is also decisive. Our study has succeeded in uncovering the drivers' attributes and habits in relation to transportation that have an impact on the likelihood of AVC. We found significant effects of several factors on the occurrence of AVCs, including factors related to driving experience and driven distances, the use of different road types, the gender of drivers and the used vehicle type. In addition to these variables, the attitudes of drivers can also be determining factors. Their approach to nature conservation and traffic safety, as well as their fear of collision, can also impact the occurrence of AVC.

As shown by the results of our research, we believe that by understanding drivers' attitudes towards AVCs, we can reduce the severity of outcomes and the frequency of occurrence of AVC in the future. Furthermore, the consideration of drivers' opinions should be given great importance as they have formulated many suggestions regarding the prevention of AVCs. Considering all this information, our research provides guidelines for developing targeted initiatives in the future to increase awareness about the significance of AVC and target those drivers who are most vulnerable to AVC.

Credit author statement

Sándor Borza: Conceptualization, Methodology, Investigation, Data curation, Writing- Original draft preparation, Writing - Review & Editing; **Laura Godó**: Conceptualization, Methodology, Investigation, Data curation, Writing- Original draft preparation, Writing - Review & Editing, Visualization; **Orsolya Valkó**: Conceptualization, Methodology, Writing- Original draft preparation, Writing - Review & Editing, Supervision; **Zsolt Végvári**: Conceptualization, Data curation, Formal analysis, Writing- Original draft preparation, Writing - Review & Editing; **Balázs Deák**: Conceptualization, Methodology, Writing- Original draft preparation, Writing - Review & Editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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