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Experiencing moose and landscape while driving: A simulator and questionnaire study

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Abstract
Animal vehicle collisions (AVC's) have large economic, medical and ecological consequences but have rarely been studied with respect to driver behaviour. The aim of this study was to investigate different AVC-relevant landscape settings (vegetation cover), with and without game fencing and in combination with encountering moose. Twenty-five participants took part in an advanced driving simulator experiment. The results show that neither the presence of a game fence nor vegetation was found to affect driving speed, speed variability, lateral position or visual scanning in general. When a moose appeared at the side of the road, the drivers reacted by slowing down earlier and reducing their speed more when no game fence was present. Furthermore, the speed reduction when a moose was present was significantly larger when the vegetation was sparse. Game fencing made drivers feel at ease whereas dense vegetation was experienced as more stressful.

1 Introduction

Sweden's ungulate population has increased over the past 50 years (e.g. Bergström & Danell 2009), as have the traffic volumes (e.g. Seiler 2004), and a similar situation prevails in several countries (e.g. Groot Bruinderink & Hazebroek 1996, Hubbard et al. 2000, Knapp 2001, Mckee & Cochran 2012). Concurrently, substantial increases have occurred in animal-vehicle collisions (AVC), with large economic, medical and ecological consequences. Seiler (2005) concludes that even if it is not cost-effective, game fencing appears to be the most efficient countermeasure, where moose-vehicle collisions could be reduced by 9% with game fencing alongside roads with adjacent forest cover and by 26% if the fencing were combined with increased roadside clearance. In addition to ungulate population density, game fencing and traffic volume, vehicle speed also affects the number of AVC's (Langbein et al. 2011) and their seriousness in terms of human injuries, especially as regards moose-vehicle collisions (e.g. Seiler 2004). In fact, a study based on 2,000 moose-vehicle accidents in Sweden shows that reduced speed is the most effective measure for reducing AVC's at any given traffic volume (Seiler, 2005). Furthermore, it has been acknowledged that driver education concerning AVC's should be an important issue for future research (Groot Bruinderink & Hazebroek 1996) and one such study (Beanland et al. 2013) show that young drivers' crash risk is not reduced, due to traditional driver training programmes. Thus, regardless if the problem with AVC's is approached with infrastructure countermeasures, with driver education or with reduced speed limits, it is important to get a better understanding of driver behaviour, speed reactions and driver experiences of wildlife while driving.

To the best of our knowledge, AVC research is mostly based on the number of AVC's or carcass animals before and after installing a countermeasure such as game fences and warning signs, and consequently not on human behaviour in specific situations involving ungulates and wildlife features. Studies combining measurements of driver behaviour (e.g. vehicle speed) with studies of drivers' experiences (e.g. feelings about driving) are not very common.

In order to bridge such a research gap the aim of this article is to study drivers' behaviour, perceptions and experience of driving in different AVC-relevant landscape settings (vegetation cover), with and without game fencing and in combination with encountering moose. Using an advanced driving simulator, drivers are analysed in terms of stress, feelings, and driving patterns, and by analysing whether drivers' subjective experiences captured by a questionnaire concurred with their actual driving patterns captured by the simulator data.

Landscape is a term with many meanings (Antonson 2011). Here we follow the European Landscape Convention's very broad definition (Council of Europe, 2000) and focus on three sections: the road with all its ramps, bridges and signposts, the section next to the road called right-of-way with shoulders, game fencing and ditches and the area further beyond this section with houses, fields and forests. All three sections are included within the Convention's definition. However, here we chose to use the term landscape for the latter section in order to distinguish it from the former two sections that are more connected to the road environment per se.

Based on the succeeding literature overview the following two research questions were developed: 1) How do different AVC-related landscape settings affect driver experience?, and, 2) In what way does the occurrence of moose and game fence affect driver experience?

2 The literature

The research literature on AVC's is vast (e.g. Hedlund et al. 2004). The research field has been categorized and structured in different ways. For instance, Gkritza et al. (2010) suggest dividing the research field into three areas: driver-focused measures, animal-focused measures, and driver and animal-focused measures. Gundersen and Andreassen (1998) suggested another subdivision, either by factors causing game to be close to traffic arteries or by factors causing vehicles to collide with game. In this paper, we mainly focus on AVC concerns related to driving behaviour in different landscape settings in combination with moose encounters. Driving behaviour research is a vast research area also in connection with AVC's, however, as can be seen below the focus is not mainly on the driver per se, but on driving in relation to statistics based on number of AVC's, permitted speed as well as the vegetation at the accident site and so on. In the following we have tried to identify features close to the road or further away that have been found to relate to AVC, under what conditions during the day and night when the animals are most likely to cross the road as well as driver behaviour in this context. Furthermore, it shall be acknowledged that we regard deer vehicle collision (DVC) as a subgroup to AVC, however, we chose to keep the DVC label in the below presentation in order not to interpret the research findings wrongly.

2.1 Spatial variations in AVC's and the influence of landscape

The roadside landscape setting is of importance to where animals are located (Finder et al. 1999, Bowman et al. 2010; Rea et al. 2010). For *forested landscapes*, Finder et al. (1999) found that the distance to forest cover is an important deer-vehicle accident predictor (Finder et al. 1999), and Seiler (2005) noted that an increased distance of 100 metres between forest cover and road might significantly reduce collisions with moose. Malo et al. (2004) noted that animals prefer to approach roads in the proximity of trees and shrubs. Similarly, concerning Sweden, Seiler (2005) found that the proximity and amount of forest habitats providing forage and cover significantly affected the risk of moose-vehicle collisions. Furthermore, Gunson et al. (2009) found that forest habitats were associated with high-kill sites in the central Canadian Rocky Mountains.

If forested landscapes, with plenty of hiding places and feed availability, were associated with AVC's, one may expect that more open *rural landscapes* are to be less exposed, but this does not appear to be the case. Lao et al. (2011) states that the probability of encountering an animal is higher in rural areas. Both Groot Bruinderink & Hazebroek (1996) and Mckee & Cochran (2012) found that the smaller the patch size of arable fields, the greater the risk of a deer-vehicle collision (DVC, not to be confused with AVC). In an American study, Iowa, Gkritza et al. (2010) studied the relationship between DVC's, deer density and land use between 1997 and 2008. A significant relationship was found between the interaction of land use and deer density. In zones with a large percentage of cropland, deer-vehicle injuries were frequent or more likely to result in injuries (c.f. Hubbard et al 2000). Other types of land highly affected by humans, such as developed areas, present a greater risk of AVC's (Neumann et al. 2012). However, Mckee & Cochran (2012) found a low probability of AVC's in large areas of urban land such as central business districts. Malo et al. (2004) found the same in the Soria province of Spain.

Beside forests and fields that may be adjacent to the road, research has also dealt with the right-of-way. For instance, according to Ng et al. (2008), roadside ditches planted with fast growing grass green up faster during spring compared to the surrounding vegetation, which for parts of the year can provide good forage opportunities for some mammals. In order to reduce the attractiveness of the roadside, the road- and rail-side areas could be mown at more strategic times (Rea 2003, Seiler & Olsson 2010), such as early summer (Rea et al. 2010).

Some studies focusing on AVC's and landscape patterns may be influenced by road density. Hubbard et al. (2000) and Mckee & Cochrane (2012) found that an increasing number of traffic lanes increased the probability of DVC's. McShea et al. (2008) found in Virginia, Clarke County, USA, that the majority (68%) of deer-vehicle accidents occurred on primary roads even though these roads constituted only 17% of the total 700 km road included in the study.

2.2 Temporal variation in AVC's

Several researchers have tried to identify time-periods of increased AVC's in temporal patterns and also tried to determine when ungulates are more likely to enter the road (e.g. Groot Bruinderink & Hazebroek 1996; Ng et al. 2008; McShea et al 2008), and their findings differ according to various properties of the regions studied. One Swedish study is of interest for our purposes. Neumann et al. (2012) followed 102 GPS-equipped adult female moose and showed that the moose are most active in the morning and afternoon for about three hours (cf. Gundersen and Andreassen 1998). This is partly in line with a study concerning DVC's that showed a higher probability of injuries on dark roads (Gkritza et al. 2010) and greater risks of moose-vehicle accidents 2–3 hours after sunrise and sunset (Haikonen & Summala 2001). According to Lagos (2012), most accidents involving roe deer occurred at dusk and dawn. It appears that the higher occurrence of AVC's at dusk and dawn is explained not only by animal-related behaviour (e.g. the rut season and other migratory aspects), but, it has been suggested, that drivers' visibility also contributes to increased occurrences of AVC's because the visibility of wild animals is reduced in twilight conditions (e.g. Høye et al. 2012).

2.3 Driver behaviour and measurement

To our knowledge, driver behaviour or the driving experience *per se* has been little investigated when it comes to AVC's. Due to the interaction between drivers' experience and reactions during driving, the study of AVC statistics does not in itself yield sufficient information for fully improving road safety and identifying effective countermeasures to reduce deaths and injuries.

Simulators have been accepted as good substitutes for on-road surveys and are used for many purposes. For example, simulators have been used to study driving behaviour in relation to road markings (Auberlet et al. 2010; Horberry et al. 2006), mobile phones (Reimer et al. 2010), driver sleepiness (Anund et al. 2008; Gershon et al. 2009), stress (Hill & Boyle 2007), steering demand and lane widths (Dijksterhuis et al. 2011), and drivers' perceptions of road and landscape features (Antonson et al. 2009, Antonson et al. 2013, Antonson et al. 2014). A large variety of validation studies indicate that simulated results are applicable in everyday road planning (e.g. Godley et al. 2002; Sechtman et al. 2009), despite the problems of the simulators' restricted visual field and total absence of the risk of injury to the 'driver' (Brown, 2001). To the best of our knowledge few studies have been performed on AVC's with the use of driving simulators.

According to many studies (e.g. Godley et al. 2002; Nilsson 2004; Elvik 2005), speed is perhaps the most important driver behaviour to control when it comes to improving traffic safety. Lao et al. (2011) found that the probability of a driver's ineffective response will increase with the speed limit. Higher traffic volumes and speed limits make DVC's more likely to occur (McShea et al. 2008, Ng et al. 2008). Other measures of driver and driving behaviour of interest to this study are the variability of speed, the lateral position, braking behaviour, mental stress and eye focus. It should also be noted that in a driving simulator study not concerning AVC per se, Antonson et al (2009) found that forests had a speed-reducing effect compared to an open landscape, and that the drivers' lateral position (the vehicle's position relative to the centre of the road) was further away from the forest.

To conclude, the literature show that the landscape setting influence the driver, and should therefore be considered a traffic safety issue. Games prefer to cross the road in certain landscape types with certain vegetation which appear to be caused by the availability of hide-outs and food. Game also prefers to cross the road during dusk and dawn. These findings will guide us in the study design concerning AVC concerns related to driving behaviour in different landscape settings in combination with moose encounters.

3 Method

The advantage of carrying out a study in a driving simulator is that several participants, without the risk of becoming injured, can drive on exactly the same route while only varying one factor at a time. In that way many factors are excluded that could obscure the effect studied. However, we argue that we cannot get the whole picture by using simulator data alone. If we do not ask the participants about their preferences, we cannot fully understand how the participants behave in different landscape settings. This is further corroborated by Kweon et al (2006), who studied the relationship between objective measures and subjective (self-reported) measures within the physical environment, and by Antonson et al. (2014), who studied driving patterns and how drivers actually perceive their driving, showing that the two do not always coincide. Therefore, we have combined the simulator data with questionnaires. When this is done in social sciences, quotation or rendering of such short stories is used in order to illustrate the participants' different opinions, or to illuminate a mutual attitude (Patton 1990).

Measurement data from the simulator (speed, lateral position and braking behaviour) together with physiological data (heart rate and eye-tracking data), oral questions and tick-box questionnaires constitute the source material of this study.

3.1 Participants

Twenty-five participants were recruited for the simulator study, 10 men and 15 women. Due to the relatively small number of participants and the complexity of the study design, the selected study population aimed towards a homogenous selection regarding age and experience. The age-span was restricted to persons born between 1960 and 1980, and the mean age in the study was 40 years (S.D. 6.4). On average, the participants drove about 15,000 km/year (S.D. 18,600) and had held a driving licence for 18.4 years (S.D. 6.5). On average they spent 26.6 per cent of their motorised time as passengers. Three participants had to abort the study due to simulator sickness, a well-known side effect (Chung, You, Kwon, Lee, Tack, Yi et al., 2007; Mourant & Thattacherry, 2000), and were replaced in an extra simulation session. All calculations refer to the 25 participants who completed a full driving session.

3.2 Driving Simulator

An advanced high-fidelity moving-base driving simulator (VTI Driving Simulator III) was used (see Figure 1). By moving, rotating, or tilting the part of the simulator containing the car body and video screens, acceleration and deceleration forces in either direction can be simulated. A vibration table enables a simulation of road surface contact. There were three forward-view channels with a total view of 115°×30° (horizontal and vertical) from the participant's position in the simulator. The test leader could always hear and see the participant, who could speak with the test leader at any time.

Figure 1. The VTI Driving Simulator III. The right-hand side of the projector dome is open and the car body (a SAAB 9–3) can be seen inside with the large video screen in front.

3.3 Design and procedure

The experiments were performed in 2011. At the simulator, the participants were given oral and written instructions on the study and their role in it, including general information about the road, simulator driving procedures, and questionnaires used. They also signed an informed consent form. The participants were then introduced to the driving simulator with a training session on a neutral 14.5 km road (right-hand traffic), to give them the opportunity to become familiar with the car's gears, steering, and acceleration. The neutral road section was flat and straight, with no passing vehicles and a homogenous roadside of dense forest without elements such as buildings or signposts.

The topography and curvature of the computer-animated road were taken from Road 621 southwest of Linköping, Sweden. The computer-animated landscape was designed based on a field trip together with the Swedish police. The Police are the organisation responsible for dealing with AVC's in Sweden. A professional tracker of injured ungulates used by the police also participated and showed us five typical AVC-sites. The different sites served as a base when designing the computer-animated landscape. A slight mist draped the landscape in order to mimic the conditions that exist when the ungulates are most active, because dusk and dawn cannot be simulated well enough in the driving simulator. The drivers are used to mist since it is very common on early cold Swedish summer mornings

The 25 participants drove eight 9-km long road stretches. The drives were continuous, with each stretch following the other without interruption. The experiment had a full factorial design with six factors: *vegetation* (dense/sparse), *game fence* (with/without), *moose* (present/absent), *radio warning message* (on/off), *speed camera* (present/absent), and *moose sign* (present/absent). The 2^6=64 different conditions were randomly assigned to the 200 road stretches (25 drivers x 8 road stretches). *Vegetation* was altered by means of forests, clear cuts, young forests, large open fields with brittle green straws of cereals, and woodland-field interfaces in predominately open habitats, with impediments covered with woods in an open field directly adjacent to the road. The *game fence* was a fixed-knot wild game fence with greenish (pressure-treated) wooden poles. The *moose* stood by the side of the road and is illustrated in Figure 2. The *radio message* warned the driver that a moose had been sighted near the village "Törneboda", the message was accompanied by a place-name sign in the simulated landscape with the name of the village. The *speed camera* was a traffic enforcement camera that is common in Sweden. A speed limit sign (90 km/h) accompanied the speed camera. Finally, the *moose sign* was a standard moose sign.

Figure 2. The landscape setting displayed in the simulator, displaying a moose.

The present study focus on the moose event. Data from the various AVC countermeasures, i.e. the radio-warning message, the speed camera and the moose warning sign, will be reported elsewhere. Only the 2-km road stretch surrounding the moose, ranging from 6,000 to 8,000 meters on the original road stretch, will therefore be considered in this study. This road segment was extracted from all 200 road stretches (25 drivers x 8 road stretches). It should be noted that the factors *fence*, *vegetation* and *moose* in the selected data subset directly affect the drivers at the location of the moose. The drivers are also indirectly primed by the factors *radio warning message* and *moose sign* (that may or may not be present during the first 5,500 metres of the original road stretch). The factor *speed camera* was not considered in the present study since it is a general speed reducing measure that was located 4500 meters away from the moose. As such it is very unlikely to affect the driver at the location of the moose.

The speed limit was set to 90 km/h, but the participants were told to drive as they would usually drive along a similar road. Between the test stretches, the participants drove a neutral, 1-km stretch. The lack of distracting features at the neutral stretch meant that the drivers were able to focus on answering the oral questions put to them as they drove. A few minutes after completing the drive, participants filled in a written questionnaire concerning their perceptions of the drive and the surrounding landscape. Each participant met one oncoming vehicle per stretch (in other words, one per 9 km), and had no other vehicles travelling in the same lane. The low traffic density ensured that the drivers did not focus on oncoming traffic, which could have interfered with their experience of AVC-related issues.

3.4 Data acquisition

Five data sources were used in the study: simulator data, physiological data, eye movement data, self-reported data and questionnaires data.

Simulator data: The sample rate of the simulator data was 10Hz. The recorded measures of interest to this study were vehicle speed, lateral position and brake pedal pressure.

Eye movement data: An eye tracker (SMI Iview® HED, SensoMotoric Instruments, Teltow, Germany) was used to determine whether the drivers actually saw the moose. The sampling frequency was 50Hz and the data were analysed using BeGaze 3.0 (SensoMotoric Instruments, Teltow, Germany) and Matlab 7.11 (The MathWorks Inc., Natick, MA, USA). The standard deviation of the radial gaze direction was calculated as a measure of the functional field of view (Recarte and Nunes, 2000).

Physiological data: An electrocardiogram (ECG, lead II) was recorded using a Vitaport 3 system (TEMEC Instrument B.V., The Netherlands) with a sample rate of 256 Hz. Wavelet denoising was applied to remove muscle noise and power line interference (Donoho and Johnstone, 1994) after which the heart rate was extracted from the ECG using a parabolic fitting technique (Zhang 2005). An increased heart rate was used as a measure of stress.

Self-reported data: A verbal question was asked after each stretch of interest in this study: 'was there anything in the surrounding environment that affected your style of driving?' The test leaders also asked if the drive felt OK.

Questionnaire data: The written questionnaire comprised multiple-choice questions. Five general questions related to the participant (for example, age and gender) and 12 questions related to driving in the simulator (in other words, how the participants experienced speed and the road in regard to ease/stress). These were followed by 19 questions about the participants' experience of road surroundings during routine driving (for example, commuting and everyday errands), asking, for example, whether they were used to driving in the countryside, how the surrounding landscape affected their driving style, and how various features of the surrounding environment affected their everyday driving pattern. Finally, there were two general questions about the participant's living conditions (for example, where they grew up and their current home).

3.5 Analyses

A series of two-way analyses of variance (ANOVA) were performed to investigate how simulator data, gaze and heart rate were affected by the factors *fence* and *vegetation*. *Participant* was included as a random factor while *vegetation, game fence* and the interaction of *vegetation* × *fence* were included as fixed factors. The factors *radio warning message* and *moose sign* were included as co-factors to avoid spurious relationships. A mixed model analysis taking participant into account was chosen, since driving behaviour responses, eye movements and stress reactions often show inter-individual differences.

The data set was divided in two subsets, one subset corresponding to road stretches when the moose was present and one subset corresponding to road stretches where the moose was deactivated in the simulation. The reason for this subdivision, in favour of simply including moose as a factor, was that tailored performance indicators were used in the two cases. It makes little sense to investigate the driver response to the moose when no moose is present (there is nothing to react to), and neither does it make sense to dilute the analyses of vegetation and game fence on general driving behaviour by including data from a critical event which clearly affects behaviour.

In the presence of a moose, the performance indicators were speed reduction, brake response and heart rate increase. *Speed reduction* was defined as the median speed minus the minimum speed for the road stretch surrounding the moose. *Brake response* was defined as the distance from the location where the driver first hit the brakes to the location of the moose. *Heart rate increase* was defined as the maximum heart rate minus the median heart rate in a segment ranging from the start of the 2-km road stretch until 200 meters after the location of the moose.

To investigate whether the factors fence and vegetation had any effect during normal driving, analyses of the performance indicators mean speed, speed variability, lateral position, and gaze variability were conducted on the 2-km road stretches where no moose was present. *Mean speed* (and *speed variability*) were defined as the mean (standard deviation) of speed. *Lateral position* was defined as the distance from the centre of the road to the centre of the vehicle. *Functional field of view* was defined as the standard deviation of the radial gaze direction, where radial gaze is calculated as the l^2-norm of the horizontal and vertical gaze components.

The Lilliefors test was used to check for normality and Bartlett's test was used to check for equal variances. In cases where the data were found to be skewed or heteroscedastic, a rank-based inverse normal transformation was applied to the data before ANOVA was conducted. The significance level was set to $p < 0.05$. For the written questionnaire data, only descriptive analyses were made. All analyses were made in Matlab 7.11 using the Statistics Toolbox 7.4 (The MathWorks Inc., Natick, MA, USA).

4 Results

Simulator data and questionnaire data were available from all participants. However, heart rate data were available from only 18 of the 25 participants. For seven of the drivers the ECG-signal was unusable, either due to synchronisation issues with the simulator data or due to technical issues with the recording device. Eye-tracking data were available from 21 out of the 25 participants. The eye-tracking system could not be calibrated for three of the drivers and the fourth driver was too tall (causing the scene camera to mostly capture the ceiling of the car instead of the projection screen in the simulator). There were also occasions when eye tracking was sporadically lost during the experiment. Regardless of whether eye tracking was available or not, the head-mounted scene camera recorded the forward view as seen by the driver. This coarse measure of the driver's head movements made it possible to determine that all drivers noticed the moose in all road stretches where a moose was present. This means that there is no confounding in the subsequent analyses due to drivers not seeing the moose.

4.1 Questionnaires

As a response to the oral question whether there was anything in the surrounding environment that affected the participants' style of driving, the participants commented upon the weather/mist, the moose, the game fence and the vegetation. The majority were concerned with the mist and the moose. One participant said that it looked as if the moose was standing on the wrong side of the game fence and a third that high vegetation along the road is not good. However, only 28 comments were passed during the 200 individually driven road stretches.

Concerning the question whether there was anything during the drive that made the participants slow down, 24 out of 25 (96%) participants answered in the affirmative. All 24 wrote that wild animals/moose were one such reason. In the follow-up tick-box question the participants could tick 19 possible reasons, but six reasons were not ticked at all (houses/buildings, broad road, game fence, open landscape, narrow road, rural fields close to road), i.e. in total they marked 13 reasons (with a total of 112 ticks) and the distribution of the major reasons for decelerating were wild animals/moose (21%), dense vegetation close to the road (10%) and a traffic sign stating end of game fence (10%).

Concerning the opposite question, i.e. whether there was anything during the drive that made the participants drive faster, 16 out of 25 (64%) participants wrote that this was the case. In this follow-up question, 11 out of 16 (69%) ticked that open landscape made them drive faster. The participants could tick the same 19 possible reasons as above (with in total 33 ticks distributed over 8 reasons) and the breakdown of the major reasons for a perceived speed increase were open landscape (33%), game fence (27%) and rural fields close to road (18%). Dense vegetation close to the road, forest curtains in an open landscape and shrubs along the road were not indicated as reasons for increasing the speed.

Concerning the question whether there was anything during the drive that made the participants feel at ease, 23 out of 25 (92%) participants answered in the affirmative and 17 out of 25 (68%) said that there was something during the drive that made them feel stressed. In the follow-up question the 23 participants could tick 10 possible reasons (making 69 ticks). The major reason for feeling calm was broad road (16%) and open surroundings (23%). The participants could also add a feature, and 6 (out of 25) added game fencing as a feature that made them feel at ease. Routine was added by another participant. In the follow-up question concerning stress, the 17 participants could tick the same 10 reasons as above (7 marked reasons, making 11 ticks), and the breakdown of the major reasons for perceived stress was dense vegetation (27%) and the test situation (27%). Only one added the game fence as such a feature and 10 added the moose and/or the mist.

Finally, 14 out of the 24 (58%) participants wrote that something in the landscape setting made them feel uncertain and insecure. Of those, 79% (11 out of 14) wrote that wild animals/moose had such a perceived effect. In this follow-up question the participants could tick 19 possible reasons (14 reasons marked and 43 ticks) and the breakdown of the major ticked reasons for a perceived insecurity were wild animals/moose (26%) and dense vegetation close to the road (16%).

The remaining questions did not concern the simulator drive *per se* but rather the participants' general experiences relating to traffic and wild animals. All 25 participants reported that they are aware of the AVC risk while driving. The primary reasons for this awareness were factors such as the time of the day, poor visibility, the type of surrounding vegetation, signposts relating to wildlife, and awareness of earlier accidents on the road. Only 16% of the participants lived in the countryside, despite 9 out of 25 (36%) driving on country roads several times a week, 40% a few times a month and 20% a few times per year. Of those driving on the countryside several times a week, 7 out of 9 answered that they usually used a single carriageway with two lanes. 17 out of 25 (68%) wrote that it was not more common to drive on motorways than on single carriageways or on even smaller roads. Regardless of the season of the year, the participants wrote that they usually drove during daytime, but a fairly large share of their total driving time occurred at dawn and twilight. 76% of the participants said that they knew someone who had been involved in an AVC. Of those 19 participants, 12 said that this had an effect on their driving pattern by decreasing their speed (75%) and making them pay closer attention to the surrounding landscape (92%). 92% (23 out of 25) said that they never felt completely safe, i.e. never felt a low risk of AVC. All participants said that they occasionally thought about AVC when driving. Table 1 shows how the participants may react when feeling AVC concern.

Table 1. Responses by the participants to the question "How do you think you would react when feeling concerned about higher risks of AVC?"

22	Reducing speed	Increasing speed	0
25	More focus on the roadside	Less focus on the roadside	0
8	Fastening seat belt	Unfastening seat belt	0

4.2 Simulator session data

When a moose appeared at the side of the road, both *game fence* and *vegetation* showed significant effects on speed (Table 2), the speed being reduced more when no fence was present (primary effect) and when the vegetation was sparse (secondary effect). On average, the speed reduction was 30.3 ± 17.9 km/h (mean ± S.D.) when no fence was present compared to 19.8 ± 16.4 km/h when a fence was present. A significant effect of *game fencing* was also found for brake response (see Table 2), with the drivers pushing the brake pedal earlier when there was no game fence. On average the drivers pushed the brake pedal 118.9 ± 49.7 metres from the moose when the fence was present, compared to 156.1 ± 54.9 metres when no fence was present. As expected, all outcome variables showed significant effects due to the factor *participant*, indicating inter-individual differences. No significant effects of *game fence* and *vegetation* were found for heart rate.

Table 2. Results (F- and p-values with degrees of freedom in parenthesis) from the two-way ANOVAs on the effects of vegetation (sparse vs. dense), fence (with vs. without) and participant, on the road stretch where the moose was present. Significant values are in bold (p<0.05).

	Vegetation	Fence	Participant	Vegetation*Fence
Speed reduction	**F(1,70)=4.23, p=0.04**	**F(1,70)=24.8, p<0.01**	**F(1,70)=3.79, p<0.01**	F(1,70)=0.05, p=0.83
Brake response	F(1,30)=0.91, p=0.35	**F(1,30)=15.13, p<0.01**	**F(1,30)=3.2, p<0.01**	F(1,30)=0.27, p=0.60
Heart rate increase	F(1,26)=0.27, p=0.61	F(1,26)=1.91, p=0.18	**F(1,26)=4.27, p<0.01**	F(1,26)=3.12, p=0.08

Figure 3 illustrates velocity, braking behaviour and heart rate in the surroundings of the moose, where data have been averaged across participants and separated according to the conditions *vegetation* and *game fence*. The velocity profile clearly illustrates that the drivers slow down earlier and more when no game fence is present. This can also be seen in the brake response profile, which shows the percentage of participants who have pressed the brake pedal at any given moment. The heart-rate profile does not show such clear tendencies, but there is a slight increase in heart rate after the moose event in the condition with dense vegetation and no fence.

In the condition where no moose was present, no significant differences due to the factors *game fence* or *vegetation* could be found in any of the outcome variables except participant (see Table 3). Figure 4 illustrates each outcome variable, averaged across participants, as a function of distance driven. The fluctuations in speed coincide with shifts in lateral position and are a consequence of the curvature of the road.

Table 3. Results (F- and p-values with degrees of freedom in parenthesis) from the two-way ANOVAs on the effects of vegetation (sparse vs. dense), fence (with vs. without) and participant, on the road stretch where no moose were present. Significant values are in bold (p<0.05).

	Vegetation	Fence	Participant	Vegetation*Fence
Mean speed	F(1,70)=1.63, p=0.20	F(1,70)=0.23, p=0.64	**F(1,70)=15.56, p<0.01**	F(1,70)=0.94, p=0.34
Speed variability	F(1,70)=1.17, p=0.29	F(1,70)=1.41, p=0.23	**F(1,70)=3.26, p<0.01**	F(1,70)=0.18, p=0.67
Lateral position	F(1,70)=0.39, p=0.54	F(1,70)=0.03, p=0.86	**F(1,70)=12.94, p<0.01**	F(1,70)=0.81, p=0.37
Gaze variability	F(1,17)=0.02, p=0.89	F(1,17)=0.88, p=0.36	**F(1,17)=2.57, p=0.03**	F(1,17)=2.93, p=0.11

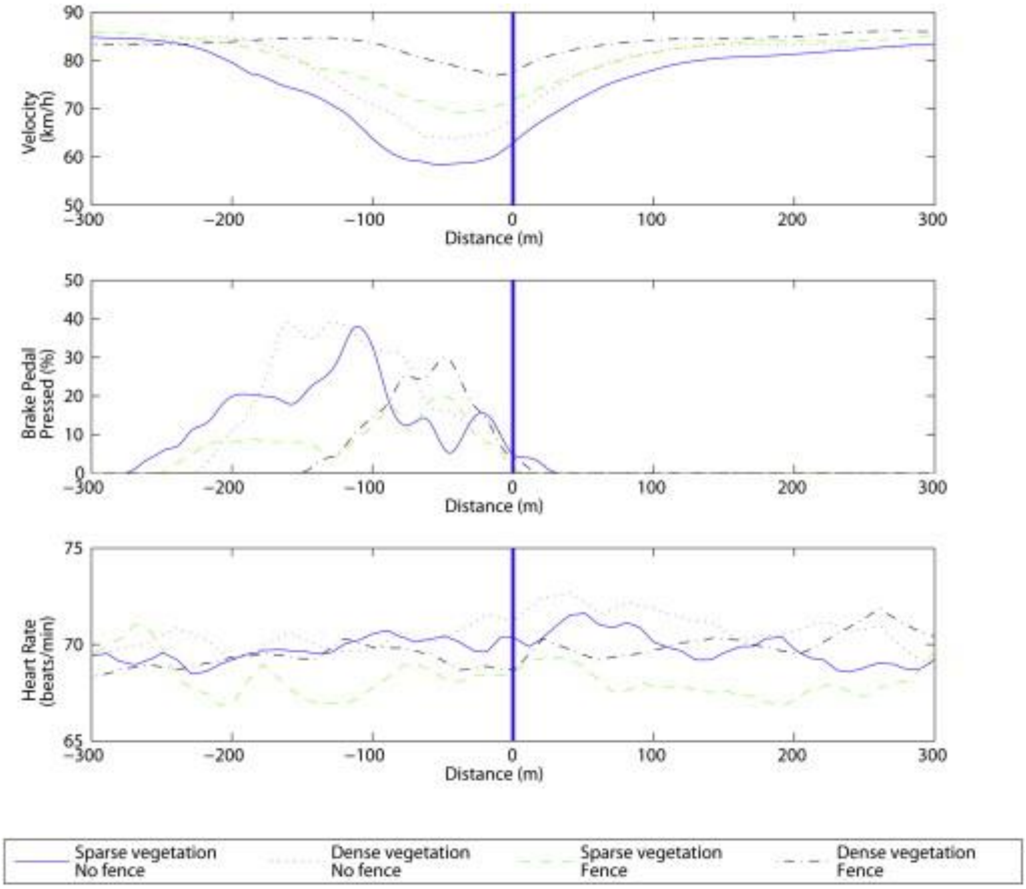

Figure 3. Profiles of velocity, brake pedal usage and heart rate, averaged across participants and plotted as a function of distance driven. The figures are centred on the location of the moose (vertical line at distance 0 meters).

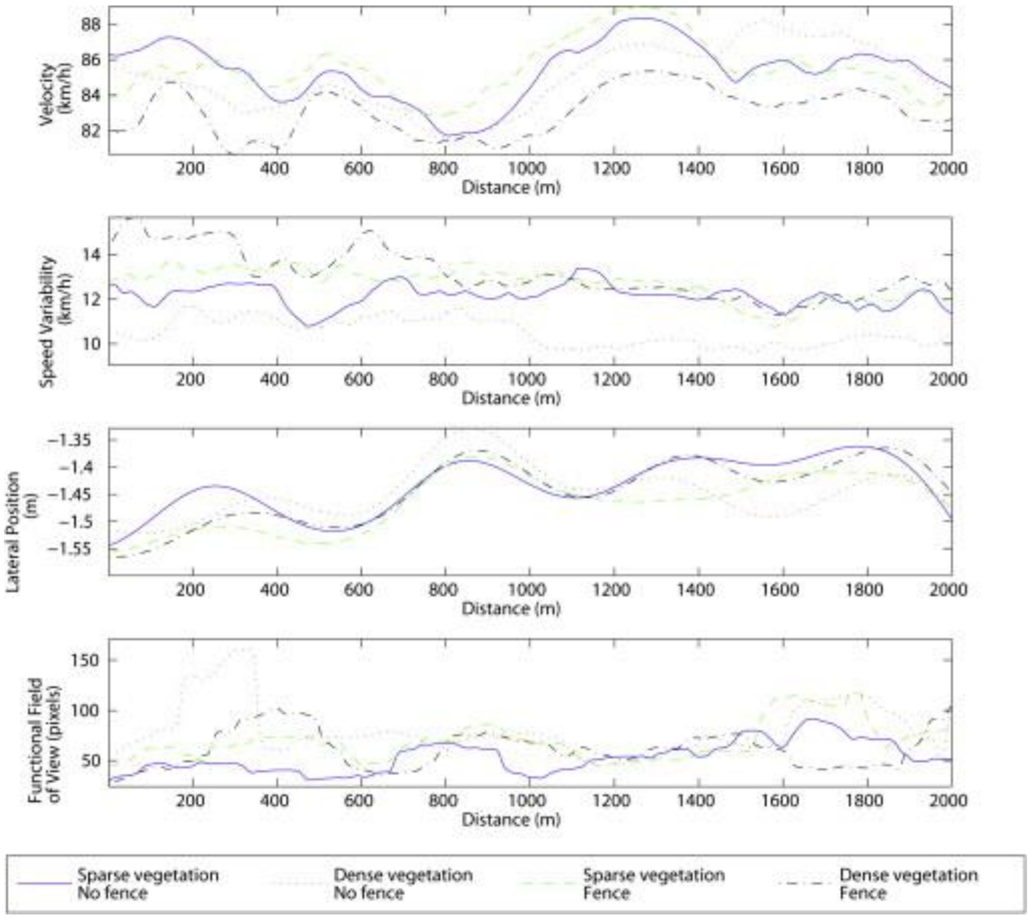

Figure 4. Profiles of velocity, variability in speed, lateral position and functional field of view, averaged across participants and plotted as a function of distance driven.

5 Discussion

The literature revealed that different types of roadside landscape settings attract ungulates and that this leads to an increased risk of AVC's. Two research questions were developed based on the literature review: 1) How do different AVC-related landscape settings affect driver experience?, and, 2) In what way do the occurrence of moose and game fencing affect driver experience?

Neither the presence of a *game fence* nor *vegetation* was found to affect driving speed, speed variability, lateral position or visual scanning in general. When the moose appeared at the side of the road, the drivers reacted by slowing down earlier and reducing their speed significantly more when no game fence was present. Furthermore, the speed reduction when a moose was present was significantly larger when the vegetation was sparse. Our interpretation of the results is as follows.

Under natural driving conditions a higher vehicle speed would lead to increased accounts of AVC's as well as more serious injuries (e.g. Seiler 2005). Game fencing is a very efficient counter-AVC measure, but is never 100% secure. In fact, a review shows that game fencing may reduce wildlife accidents by 92% or cause an increase of 22–120% (Høye et al. 2012). Irrespective of these heterogeneous effects of fencing, drivers appear to feel safer and more secure when the game fence is present, since the general and perceived risk for AVC's is very low compared to unfenced road stretches. This was also verified by the questionnaire data in this study, where many participants perceived game fencing as one reason for feeling at ease during the drive. This feeling of safety has been reported to encourage drivers to compensate the reduced risk by increased speed (Wilde 1982, Näätänen and Summala 1976). This result is verified by our questionnaire data, but could not be further confirmed by the simulator data where no significant change in vehicle speed was found due to the factor *game fence*. However, even though the drivers did not increase their speed due to the fence *per se*, they did react more forcefully to a dangerous event when the fence was absent.

It has previously been found that participants experience less stress, drive faster, and closer to the roadside when driving in open landscapes (Antonson et al. 2009). In the same study the participants also grasped the steering wheel more often which was interpreted as a sign of stress making the results contradictory, however, it may be explained by the increased speed which requires increased contact with the steering wheel in order to quicker follow road curvature (Antonson et al. 2009). The participants' subjective feelings in this study agree with some of these findings – dense vegetation is experienced as insecure and more stressful, something that was also indicated by the slight, but insignificant, increase in heart rate in the condition with dense vegetation and no fence. However, the simulator data did not show any significant differences on general driving behaviour due to the factor *vegetation*. Based on the data in Figure 4, the reason for this may be that the impact of vegetation is small compared to the variations caused by the geometry of the road.

The response to encountering animals when driving is highly dependent upon visibility, as has been demonstrated in several studies analysing the correlation between roadside clearance and the risks of AVC's. Seiler (2005) studied AVC's in Sweden and found that moose-vehicle collisions were more frequent on roads adjacent to clear cuts and young forests compared to similar roads in farming country. Furthermore, in Spain, Malo et al. (2004) noted that animals preferred to approach roads in the proximity of trees and shrubs. In this study, we found that the driver reduced the speed more when the vegetation was sparse, probably because of improved visibility, which, in turn, allows a more prompt response. If Seiler's (2005) results still hold good, the study of driver behaviour in a context of different vegetation types (height and age) is of great research interest. Earlier it has been said that in order to reduce the attractiveness of the roadside, the roadside areas could be mown at more strategic times (Rea 2003, 2010, Seiler & Olsson 2010). Different types of maintenance are thus also of interest for future driving simulator studies, for instance how different tree species and their age, following maintenance measures such as clearance and harvesting, affect the drivers' experience. It may seem contradictory that the results indicate increased driver stress (subjective feeling) in dense vegetation settings (with no fence) while sparse vegetation led to a lower speed, which also is indicative of increased stress. We cannot fully explain this contradiction, however, it should be noted that there was no significant speed reduction while driving in the dense forest setting. It is a plausible possibility that the factor *vegetation* in this study was not studied for a sufficiently long interval i.e. that the length of different vegetation types was made to short in the design of the study. It is important that the vegetation effect on driver behavior should be investigated further in future studies.

Unfortunately, since it is impossible to know the exact causality of accidents in studies analysing wildlife accidents *ad hoc* because they have not been performed under controlled experimental conditions, it is not possible to separate impacts of driving behaviour or visibility from impact of e.g. increased abundance of moose due to environmental or landscape conditions. However, findings reported by Neumann et al. (2012), who studied moose migration patterns and moose vehicle accidents in Northern Sweden, suggest that efforts to reduce collisions should focus on driver attitudes and road conditions, since higher collision risks were shown to be primarily explained by low light levels and poor road surface conditions rather than moose movement patterns.

At night, few motorists are able to detect a deer until they are within 50 m of it (Mastro et al. 2010). Our results show that drivers started to brake as early as within 156 m (no game fence) and 119 m (with game fence) of the moose. Although since the driving conditions between our study and that of Mastro et al. (2010) are very different (i.e. different speed limits of 90 km/h in our study and 46 km/h in Mastro et al. (2010) and differed between day and night conditions, respectively), and the animal decoy was placed at different distances from the road, it is difficult to directly compare the results. Since many and severe AVC's occur in night conditions, it would be interesting to perform a study with the same variables (game fence, vegetation and moose) but with lighting conditions corresponding to dusk, dawn and night-time. If our study had been conducted in these conditions, the visibility distance and brake responses would probably have been different and perhaps more similar to results shown by Mastro et al (2010), with lower visibility distance of animals.

The participants age pool was in this study kept to those aged between 30 and 50 years in order to eliminate any aging effects, however, in future studies it would be of interest to study also young and older adults.

More information can be extracted from the eye-tracking data, such as the number of fixations on a gaze target and the total glance time. However, it was decided not to extract this information since it is not really interesting in the extreme event of a moose standing by the side of the road. A driver who has noticed a moose will definitely look at the moose, and he/she will continue to do so until the moose can no longer be seen. What is interesting is whether you take precautionary actions or not. This was mainly investigated in terms of changes in speed or via questionnaires in this study. Regarding eye movements, it is, however, interesting to see if the different conditions changed the scanning behaviour on a general level. This was not the case in this study. One reason for the absence of significant effects may be that the functional field of view was underestimated. This is a direct consequence of calculating the functional field of view as the standard deviation of the radial gaze based on data from a head-mounted eye tracker. However, since eye and head movements generally correlate to a large extent (Metz & Kreuger, 2010), the results should be valid on a relative level.

This study contributes with important fundamental knowledge on driving behaviour in an AVC context. Such knowledge may, for instance, be used in driver training. By using less expensive fixed base driving simulators, the learning drivers can experience different landscape scenarios (e.g. vegetation density, game fence, mist, dusk and dawn) known to attract ungulates in respective region or country, and also see the effect of their possible real driving behaviour. Such driving simulators have proven to work well within normal driver training (e.g. Wade et al. 2005; Kappé et al. 2005; Falkmer & Gregersen 2003).

6 Conclusions

The literature show that there exist an abundant body of research in the field of AVC, however, studies combining measurements of driver behaviour (e.g. vehicle speed) with studies of drivers' experiences (e.g. feelings about driving) are not very common, and in particular, studies using driving simulators are scarce. Driving simulators are good and safe substitutes for real-life driving. In general, game fence and vegetation did not affect driving speed, speed variability, lateral position or visual scanning. However, when the moose appeared in the landscape the drivers slowed down earlier and their speed was more significantly reduced when no game fence was present. Game fencing were perceived as one reason for the drivers for feeling at ease during their drive, however, they did not increase their speed due to the factor *game fence*. Another subjective feeling is that dense vegetation was experienced as insecure and more stressful. This was also indicated by an increased heart rate in the condition with dense vegetation and no fence.

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