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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, Danielson, & Schmitz, 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, Putman, & Pokorny, 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 2000 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, Goodie, Salmon, & Lenné, 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

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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, Curtis, Curtis, & Williams, 2004). The research field has been categorised and structured in different ways. For instance, Gkritza, Baird, and Hans (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 (Bowman, Ray, Magoun, Johnson, & Dawson, 2010; Finder, Roseberry, & Woolf, 1999; Rea, Child, Spata, & MacDonald, 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 m between forest cover and road might significantly reduce collisions with moose. Malo, Suárez, and Díez (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, Clevenger, Ford, Bissonette, and Hardy (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, Zhang, Wu, and Wang (2011) states that the probability of encountering an animal is higher in rural areas. Both Groot Bruinderink and Hazebroek (1996) and Mckee and 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 and 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, Nielsen, and St. Clair (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 and Cochran (2012) found that an increasing number of traffic lanes increased the probability of DVC's. McShea, Stewart, Kearns, Liccoli, and Kocka (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; McShea et al. 2008; Ng 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 3 h (cf. Gundersen & 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 h after sunrise and sunset (Haikonen & Summala, 2001). According to Lagos, Picos, Valero, (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, Elvik, Sørensen, & Vaa, 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