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The effects of driving events on the stability and resting behaviour of cattle, young calves and pigs

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Abstract

*The welfare of animals in transit may be affected by driving events, such as acceleration, braking and cornering. The relationships between driving events and the behavioural responses of the animals were examined. A single-deck, non-articulated vehicle was fitted with a video-recording system, GPS and tri-axial accelerometer. Two drivers each drove three standard journeys (two 3-h stages on different types of roads) for each animal type. Six different groups of five cattle (*Bos taurus*), ten calves and ten pigs (*Sus scrofa*) were each transported on separate journeys. Cattle stood still for most of each journey. Calves spent more time lying down during the second stage of the journey than during the first. Although pigs spent some of the time lying down, they spent more time sitting down and this time was greatest on a motorway and during the second stage of the journey. Frequent adjustments to maintain stability were required in response to acceleration, braking, cornering and rough road surfaces. Some animals experienced repeated falls. Falls occurred after a series of different types of events. The fewest losses of balance occurred on the motorway. As a motorway is a limited access multi-lane carriageway not crossed on the same level by other traffic lanes, the driver does not normally undertake frequent vehicular adjustments to respond to road features. Therefore, motorways give animals an opportunity to rest and avoid discomfort from repetitive driving events. If drivers anticipate potential driving events and prepare for them, it will reduce the likelihood and severity of losses of stability.*

Keywords: *animal welfare, behaviour, calves, cattle, pigs, transport*

Introduction

Many factors can affect the welfare of cattle (*Bos taurus*), calves and pigs (*Sus scrofa*) during transportation (Grandin & Gallo 2007; Lambooij 2007). One important factor is the risk of injury, distress and disturbance to rest that can occur as a result of vehicle movement. For example, sudden braking can result in cattle sliding to hit each other and the interior of the vehicle, and some may fall over (Lambooy & Hulsegge 1988). In a series of papers, summarised by Tarrant (1990), it was shown that cattle lose balance frequently in response to driving events, but on most occasions they move their feet in time to regain their balance. Gebresenbet *et al* (2011) considered that driving conditions (road surface and curvature), poor driving style (variations in speed and vibration) and poor suspension were the main factors causing vibration and loss of balance experienced by animals during transport.

Gebresenbet *et al* (2011) showed that vibration from the floor of a moving livestock vehicle (recorded using an accelerometer) can be transmitted to cattle (wearing an accelerometer on their chest). There have been several studies on the relationships between vibration and the physiological and behavioural responses of the animals. These studies have shown that vibration: is stressful in both calves (Locatelli *et al* 1989) and pigs (Perremans *et al* 1998); is aversive to pigs (Stephens *et al* 1985); can disturb the resting behaviour of pigs (Bradshaw *et al* 1996a,b; Peeters *et al* 2008) and might cause motion sickness in pigs (Randall & Bradshaw 1998).

Accelerometer recordings made in three axes (longitudinal, lateral and vertical) from a livestock vehicle, driven on a variety of road types, will consist of a combination of vibrations and shocks. Rouillard (2002) described shocks as short-duration, relatively high-amplitude events that occur randomly and are produced in response to a driving event, such as braking, cornering or a pothole: "In vehicles, shocks are often manifested as large and short-duration vibration bursts and usually occur within a background of random vibrations". When shocks are identified the amplitude of the event lies outside the normal background vibration (Rouillard 2002).

Since random high magnitude acceleration events (shocks) are likely to pose the greatest risk of loss of postural stability, this study examined the effects of acceleration in

Table 1 Details of animals and journeys.

Type of animal		Group details					Journey details		
		Group size	Mean (± SD) live weight (kg)	Mean (± SD) age	Pen size (m)	Space allowance (m² per animal)	Median duration (h) (Q_1–Q_3) 1st stage	2nd stage	Mean (± SD) temperature (° C)
Cattle (*Bos taurus*)	Charolais × 3 steers and 2 heifers	5	370 (± 53)	316 (± 49) days	2.67 × 2.12	1.13	3.20 (2.94–3.62)	3.45 (3.10–3.77)	7 (± 3.42)
Calves (*Bos taurus*)	Holstein-Friesian or Holstein-Friesian × 5 bulls and 5 heifers	10	59 (± 6.5)	28 (± 6) days	1.62 × 2.12	0.34	3.06 (3.03–3.23)	3.03 (2.94–3.14)	8 (± 5.68)
Pigs (*Sus scrofa*)	Large White × Landrace boars and gilts[1] from stable social group	10	111 (± 10)	6 months[2]	2.10 × 2.12	0.45	2.44 (2.35–2.48)	2.72 (2.59–3.05)	10 (± 6.28)

[1] 5 boars and 5 gilts on four journeys, 3 boars and 7 gilts on one journey and 6 boars and 4 gilts on one journey.
[2] Approximately.

three axes on the responses of cattle, calves and pigs by identifying driving events composed of shocks that exceeded threshold values. Although several studies on cattle (Kenny & Tarrant 1987a,b; Tarrant *et al* 1988, 1992) and sheep (Cockram *et al* 2004) have recorded different types of driving events and the stability of the animals in response to these events, this relationship has not previously been reported in detail for calves and pigs. The current study was also able to use a combination of equipment (video recording, accelerometer and GPS [Global Positioning System]) to quantify driving events and the behavioural responses to these events, and software to integrate these various recordings on a common time code.

Materials and methods

A 7.5-tonne, single-deck, non-articulated livestock vehicle with manual transmission was fitted with a video-recording system. Two cameras at different angles recorded the animals in the livestock area and supplementary lighting was used. The livestock pen was formed using a weld-mesh partition and a metal tread-plate floor was covered with shavings and/or straw. In the driver's cabin, one camera recorded the driver, a second camera recorded the driver's view through the windscreen and a third camera recorded the speedometer. Separate, continuous, colour recordings on video tape were made from each camera from the time the animals were loaded until they were unloaded. A vehicle monitoring system (an adapted 'Inovas Capture Cube', Inovas, Falkirk, UK) was installed on the livestock vehicle and used to record data on a common time code with that used for the video recordings. The system contained a tri-axial accelerometer ('Inovas Total Sense', 3 Axis G sensing option with ± 2 g sensitivity, Inovas, Falkirk, UK) located on the chassis underneath the livestock compartment for longitudinal (acceleration and braking), lateral (cornering) and vertical (roughness of road surface) acceleration recordings, and a GPS system (located on the roof of the vehicle) for both vehicle speed and route mapping. The term 'acceleration' refers to the rate of change of velocity with time, in any direction, eg from all three axes of an accelerometer, but in common usage it refers to an increase in speed by a vehicle in one dimension. In this study, the term 'acceleration' (without any prefixed modifying term such as lateral or vertical) is used below to describe positive longitudinal acceleration and the term 'braking' is used to describe negative longitudinal acceleration or deceleration. Lateral acceleration occurs during cornering. Vertical acceleration can be used to estimate road roughness (Gonzalez *et al* 2008). Road roughness is a broad term to describe deviations of a road surface from a flat plane. This includes potholes, cracks and random variations in the surface of the road, especially on dirt or gravel roads that are not paved with a durable surface. The roughness of the road surface is related to the severity of the shocks and vibration recorded as vertical acceleration. The data were logged onto a computer using an adapted version of 'Inovas Capture Cube Software' (Inovas, Falkirk, UK). Air temperature in the livestock compartment was recorded at 5-min intervals using Tinytalk Data Recorders (Orion Components, Chichester, UK).

The cattle, calves and pigs were spray-marked with different coloured numbers for individual animal identification. Each animal was transported on only one journey and had no previous experience of transportation. Two male drivers (with 30 years of experience as stockmen and of transporting livestock) drove three journeys each for each type of animal (Table 1). The drivers were asked to drive the vehicle in their normal driving style. For each journey, the

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route was divided into two journey stages of approximately equal duration that were separated by a 0.5 to 1 h driver rest break. The livestock remained onboard the vehicle during the driver rest break. Within the first journey stage, the vehicle travelled for approximately 1 h on minor roads, then 1 h on main roads and another hour on a motorway. For cattle and calves, the vehicle returned along the same route, but the pigs were transported to a slaughterhouse.

For parts of some journeys, some technical problems occurred that resulted in a loss of either vehicle data or video recordings. This affected some portions of four cattle journeys, two calf journeys and two pig journeys. Using recordings of the speedometer as a guide, the speed recorded by the vehicle logging system (logged each second) was edited for errors arising from GPS signal drop-out to remove speeds that were > 130 kph.

With the exception of the driver's main rest period, the videotapes of the driver, driver's view of the road ahead and the recordings of the behaviour of the animals were observed and behavioural observations were recorded using 'Observer' software (Noldus, Wageningen, The Netherlands). The posture of two randomly selected focal animals from each journey were observed and recorded as standing still, moving, kneeling or lying down. For pigs, sitting down was also included. Losses of stability were categorised as either: losses of balance (sudden and rapid movement of the shoulder, pelvis or feet), slides (rapid movement of the whole body without perceivably lifting feet or falling), struggle (rapid repetitive movement of legs in an attempt to regain stability) or falls (rapid drop that results in contact of the body with the floor). Interactions between a focal animal and any other animal were also recorded as: trampling, butting, pushing, kicking and mounting. However, these interactions and struggles were infrequent and are not described any further.

Road type and the time spent on each road type were identified from the video recordings and specialised software (based on 'Video Route Trainer', Inovas, Falkirk, UK). This software was adapted for the vehicle monitoring system and enabled the logged co-ordinates of the vehicle location to be plotted on digital maps of the route. Road type was categorised by the colouring and letter labels used for road types on UK Ordinance Survey maps. A motorway (highway), ie an express route consisting of a limited access, multi-lane carriageway not crossed on the same level by other traffic lanes and for the exclusive use of certain classes of motor vehicles, was identified on the maps by the colour blue and the label 'M'. Main roads, ie non-controlled-access principal roads that on this route were single-carriageway roads, were identified on the map by the colour red or green and the label 'A'. Minor roads were categorised as all other road types on the route, usually with a lower traffic density. They consisted of roads designated as B-roads (coloured orange and labelled 'B') and unclassified roads (coloured either yellow or white). Both minor and main roads passed through urban areas, such as villages and towns. The recordings of the driver were used to identify when the driver performed a gear change. The times when the driver changed gear and when the road type changed category, were recorded using the Observer software. The readings obtained from the vehicle monitoring system were used to categorise the intensity of longitudinal, lateral and vertical acceleration into three categories (> 0 to 0.1 g; > 0.1 to 0.5 g; > 0.5 to 2 g). The speed of the vehicle was divided into seven speed categories (0; > 0 to 40; > 40 to 50; > 50 to 80; > 80 to 100; > 100 to 110; > 110 to 130 kph). These edited vehicle recordings were then merged into 'Observer' files using the common time code.

The 'Observer' software was also used to calculate the duration and frequency of driver behaviour, driving events and the behavioural responses of individual animals. Each journey was divided into the first stage (Stage 1), before the driver's main rest period and the second stage (Stage 2), after the driver's main rest period. Within each of the first and the second journey stages, the durations and frequencies of observations made during a road type were combined. The effects of Driver, Road type (Road) and Stage of journey (Stage) on the frequency of driving events, vehicle speed and the behaviour of two randomly selected focal animals from each journey were examined using mixed and generalised linear models (Statistical Analysis Systems Institute [SAS] 2000), as used by Cockram *et al* (2004). Normal mixed models, with random effects fitted for animals and interaction between animals and journey were used to analyse treatment effects on behavioural states. For variables based on the number of observations of an event during a period 'at risk', generalised linear models were used. A negative binomial distribution was used for the number of driving events and a Poisson distribution was used for the number of behavioural events.

To examine the temporal relationships between either driver behaviour or driving events and the responses of one focal animal per journey, the 'Observer' software was used to perform a lag sequential analysis. The percentage of losses of balance and the percentage of slides that could potentially have been caused by each single driving event during the preceding 5 s was calculated. The 'Observer' files were observed to identify the sequence of events during the 5 s before a fall by each focal animal.

Results

Effect of driver, journey stage and road type on driving events

Road type had a major influence on the speed, and occurrence of driving events (as recorded by longitudinal, lateral and vertical acceleration events and the frequency of gear changes) (Table 2). The influence of the driver was not as large, but there were significant interactions for driver with both road type and journey stage. There were also significant interactions between road type and journey stage. Figure 1 shows the percentage of time that the vehicle was driven within each speed category for each road type during cattle journeys. A similar pattern occurred during calf and pig journeys. The speed of the vehicle was significantly

Table 2 Significant effects of driver (D), road type (R) and stage of journey (S) on speed and driving events.

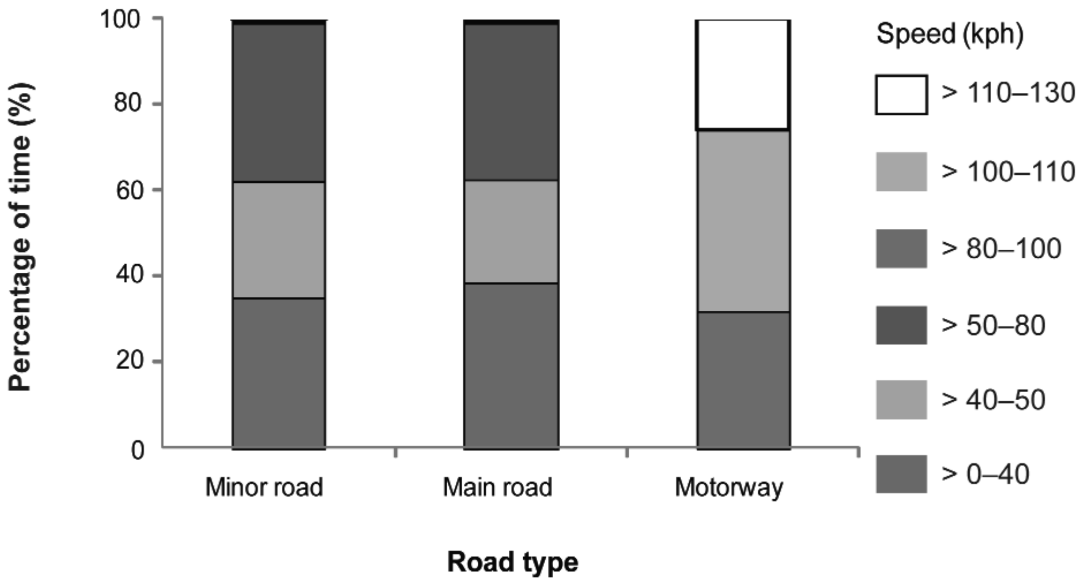
Variable	Animal	Statistical significance						
		D	R	S	D × R	D × S	R × S	D × R × S
Speed (kph)								
0–40	Cattle		***					
	Calves		***			*	*	
	Pigs		***					*
> 40–50	Cattle		***					
	Calves		***					
	Pigs		***					
> 50–80	Cattle		***					
	Calves		***				*	
	Pigs		***			*		
> 80–100	Cattle		***			*		*
	Calves	*	***		***	*		
	Pigs		***			*		
> 100–110	Cattle		***				*	
	Calves		***					
	Pigs		***					
> 110–130	Cattle		***		*			
	Calves		***					
	Pigs	*	***	*	**		*	
Acceleration (g)								
> 0 to 0.1	Cattle	***	**		*	*	***	
	Calves		***		***			
	Pigs	*	***			*		
> 0.1 to 0.5	Cattle		***	**		*	*	**
	Calves	**	***	*	***			
	Pigs		***	**				
Braking (g)								
> 0 to 0.1	Cattle	**	***	**	*	*	*	**
	Calves	**			***			
	Pigs		*	**				**
> 0.1 to 0.5	Cattle		***	***		*	***	
	Calves	*	***	*	**	**	***	***
	Pigs		***	**			***	***
Cornering (g)								
> 0 to 0.1	Cattle		***				*	*
	Calves		***	***	**		***	
	Pigs		***		*			
> 0.1 to 0.5	Cattle		***				**	**
	Calves		***	***	**		***	
	Pigs		***		*			
> 0.5 to 2	Cattle		***				***	***
	Calves		***	**	**		***	
	Pigs[1]		***	***	***	**	***	

Table 2 (cont)

Variable	Animal	Statistical significance						
		D	**R**	**S**	**D × R**	**D × S**	**R × S**	**D × R × S**
Vertical acceleration (g)								
> 0 to 0.1	Cattle	***	***		**	**	***	
	Calves	*	***		***			
	Pigs		***	***	***	**	***	
> 0.1 to 0.5	Cattle	***	***		***	**	***	
	Calves	*	***		***	*		
	Pigs		***		*			
> 0.5 to 2	Cattle	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Calves	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Pigs[1]		***	***	***	**	***	
Frequency of gear changes (number per h)								
	Cattle	*	***				***	***
	Calves		***		***			***
	Pigs		***		***		***	

[1] As there were no events on the motorway, this analysis did not include motorway within road type.
n/a: Due to the low occurrence of this type of event, this analysis was not undertaken. * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Figure 1



Percentage of time that the vehicle was driven within each speed category on each road type, during cattle journeys.

Table 3 Percentage of losses of balance that were preceded within 5 s by driving events.

Driving event	Category (g)	Percentage of losses of balance preceded by driving event		
		Cattle	Calves	Pigs
Acceleration	> 0 to 0.1	32.1	28.0	33.6
	> 0.1 to 0.5	20.1	15.0	15.8
Braking	> 0 to 0.1	29.6	25.5	29.8
	> 0.1 to 0.5	11.3	8.1	8.7
Cornering	> 0 to 0.1	37.9	35.5	39.2
	> 0.1 to 0.5	41.1	40.4	45.7
	> 0.5 to 2	0.9	0.8	0.5
Roughness of road surface	> 0 to 0.1	27.3	33.2	35.9
	> 0.1 to 0.5	26.8	33.0	35.7
	> 0.5 to 2	0	0.02	0
Gear change		13.6	9.8	10.4
Frequency of loss of balance (number of events per animal per h)[1]		181	200	311

[1] Total of number of losses of balance for all focal animals/total duration of observation periods/number of journeys.

Table 4 Percentage of slides that were preceded within 5 s by driving events.

Driving event	Category (g)	Percentage of slides preceded by driving event		
		Cattle	Calves	Pigs
Acceleration	> 0 to 0.1	54.3	21.6	53.8
	> 0.1 to 0.5	40.4	27.0	43.6
Braking	> 0 to 0.1	46.8	24.3	48.7
	> 0.1 to 0.5	8.5	8.1	20.5
Cornering	> 0 to 0.1	42.6	32.4	41.0
	> 0.1 to 0.5	46.8	37.8	51.3
	> 0.5 to 2	0	8.1	2.6
Roughness of road surface	> 0 to 0.1	28.7	51.4	51.3
	> 0.1 to 0.5	25.5	29.7	51.3
Gear change		35.1	32.4	10.3
Frequency of slides (number of events per animal per h)[1]		3	1	2

[1] Total of number of slides for all focal animals/total duration of observation periods/number of journeys.

faster on motorways than on minor or main roads. For almost all of the time on the motorway, the vehicle was driven at speeds faster than 80 kph. On minor and main roads, the vehicle was driven at speeds slower than 80 kph for 98% of the time. Effects of road type on speed are not described in detail. For cattle journeys, during Stage 1, Driver A drove between > 80 and 100 kph for 36% of the time on the motorway, whereas Driver B only drove within this speed range for 22% of the time. Both drivers drove for longer on the motorway section at speeds between > 100 and 110 kph during Stage 2 (44%) than during Stage 1 (36%). During the motorway section, Driver B drove for longer (31% of the time) at speeds between > 110 and 130 kph than Driver A. For calf journeys, on the motorway, Driver B drove the vehicle at speeds of between > 110 and 130 kph for a greater percentage of the time (46%) than Driver A (29%). Also, for calf journeys on the motorway, the vehicle was driven for a greater percentage of time at speeds between > 110 and 130 kph during Stage 1 (46%) than during Stage 2 (30%). For pig journeys on minor roads,

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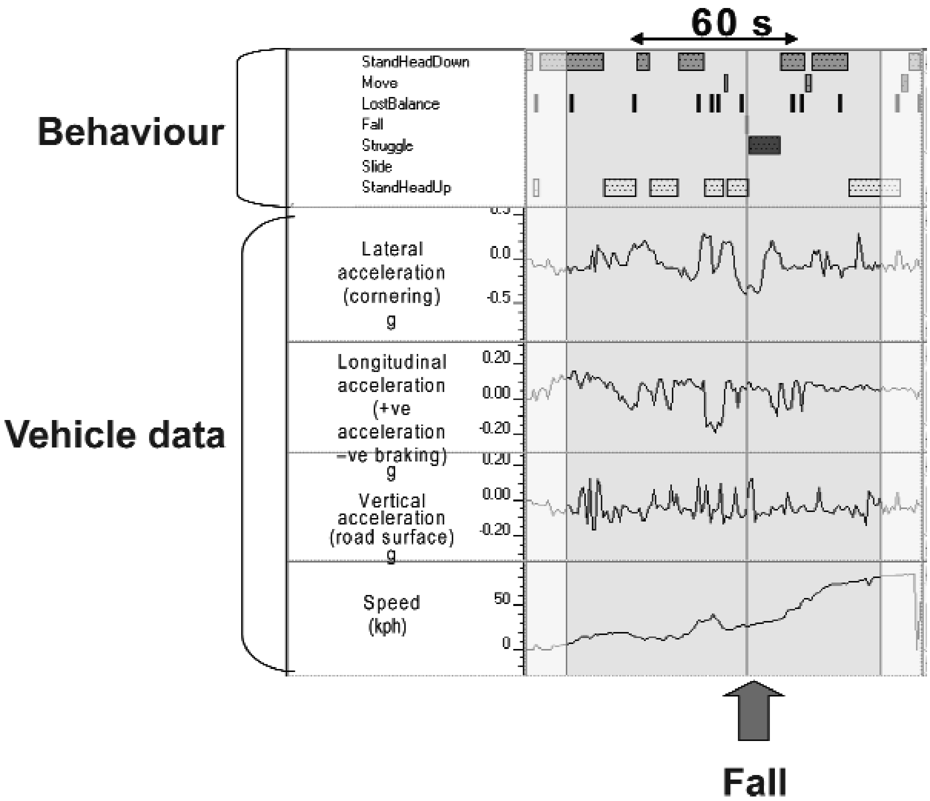
Figure 2



An example of lateral, longitudinal and vertical acceleration recordings, vehicle speed and cattle behaviour before and after a fall during a journey.

during Stage 1, Driver A drove the vehicle for a greater percentage of the time (46%) at speeds between > 0 and 40 kph than Driver B (31%), but during Stage 2, Driver B drove the vehicle for a greater percentage of time at these speeds than Driver A. For pig journeys on minor roads, Driver A drove the vehicle between > 0 and 40 kph for a greater percentage of time during Stage 1 (46%) than during Stage 2 (29%), but Driver B drove the vehicle between > 0 and 40 kph for a greater percentage of time during Stage 2 (42%) than during Stage 1 (31%).

There were numerous significant effects on driving events, but only the main significant effects, ie where the magnitude of the difference was at least four times, are described. No acceleration or braking events greater than 0.5 g were recorded. The effects of driver, road type and journey stage on vertical acceleration were not large and are not described in detail.

On the cattle and pig journeys, both drivers were between 4 and 17 times more likely to have accelerations between > 0.1 and 0.5 g on minor roads than on motorways (95% CI for cattle 2–24 and for pigs 14–21). On pig journeys, on main roads, accelerations between > 0.1 and 0.5 g were 11 times (95% CI 9–14) more likely than on the motorway. On cattle journeys during Stage 1, both drivers were between 11 and 12 times more likely to have accelerations between > 0.1 and 0.5 g on main roads than on motorways (95% CI 5–21).

For both drivers during both stages, braking events between > 0.1 and 0.5 g, were more likely (95% CI for cattle 8–11, for calves 8–13 and for pigs 12–30) on minor roads than on motorways and more likely on main roads than motorways (95% CI for cattle 5–7, for calves 6–9 and for pigs 7–16). During calf journeys on the motorway, Driver B was four times (95% CI 2–11) more likely to brake between > 0.1 and 0.5 g during Stage 1 than during Stage 2, whereas during pig journeys, this was six times more likely to occur during Stage 2 than during Stage 1 (95% CI 2–19). On calf journeys, on main roads during Stage 2, Driver B was four times (95% CI 1.5–8.3) more likely than Driver A to brake between > 0.1 and 0.5 g.

Although for some journeys there were interactions between driver, journey stage and road type, in general, cornering events between > 0.5 and 2 g were more likely to occur on minor roads and on main roads than on the motorway. On pig journeys on the motorway, there were no cornering events between > 0.5 and 2 g. The effects of driver, road type and journey stage on cornering events between > 0.1 and 0.5 g were not large.

On minor and main roads, gear changes were at least six times (95% CI for cattle 5–9, for calves 16–40 and for pigs 33–119) more likely than on the motorway.

Table 5 Percentage of falls that were preceded within 5 s by driving events.

Driving event	Category (g)	Percentage of falls preceded by driving event		
		Cattle	Calves	Pigs
Acceleration	> 0 to 0.1	57.1	62.1	25.0
	> 0.1 to 0.5	57.1	44.8	33.3
Braking	> 0 to 0.1	42.9	48.3	25.0
	> 0.1 to 0.5	14.3	20.7	50.0
Cornering	> 0 to 0.1	35.7	48.3	50.0
	> 0.1 to 0.5	71.4	62.1	58.3
	> 0.5 to 2	7.1	3.4	8.3
Roughness of road surface	> 0 to 0.1	57.1	58.6	50.0
	> 0.1 to 0.5	57.1	58.6	50.0
Gear change		7.1	31.0	16.7
Frequency of falls (number of events per animal per h)[1]		0.07	0.15	0.08

[1] Total of number of falls for all focal animals/total duration of observation periods/number of journeys.

Table 6 Sequence of events 5 s before a fall in cattle.

Journey number	2		3	4			5							
Fall by focal animal	1st	2nd	1st	1st	2nd	3rd	1st	2nd	3rd	4th	5th	6th	7th	8th
Time before fall when events occurred (s)														
5		↑	↓ LOB			LOB	↔↔ ∩∩		↑ ↔↔		↓	∩∩	↔ LOB	↔
4	↑↑∩∩	↑↑	↑	↓↓ ↔↔	LOB ↔↔	↔ ↔↔	↔↔ ∩ LOB	LOB	∩ LOB	↔↔ ∩	LOB ↑	∩	↓	
3	LOB ↔↔↔		LOB ↑↑		LOB ↓↓	∩∩ LOB			↑↑ ∩∩ LOB	Gear LOB	LOB ↔↔		↔↔	↔↔
2	LOB↑↑			LOB ↑↑ ∩∩	MOV ↑↑		↓↑	↑↑ ∩∩ LOB	LOB ∩	↑↑ LOB	LOB	↓ ∩∩ ∩	LOB	LOB
1	LOB ↔↔ ∩		↓ ↔	↓	↑ ↔↔ ∩	∩	LOB		↔			↑ LOB	∩∩ ↔↔ ∩	↑

MOV = move; LOB = loss of balance; ↑ = acceleration > 0 to 0.1 g; ↑↑ = acceleration > 0.1 to 0.5 g; ↓ = braking > 0 to 0.1 g; ↓↓ = braking > 0.1 to 0.5 g; ↔ = cornering > 0 to 0.1 g; ↔↔ = cornering > 0.1 to 0.5 g; ↔↔↔ = cornering > 0.5 to 2 g; ∩ = vertical > 0 to 0.1 g; ∩∩ = vertical > 0.1 to 0.5 g; Gear = gear change.

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Table 7(a) Sequence of events 5 s before a fall in calves.

Journey number	1		2			3				4		5			
Fall by focal animal	1st	2nd	1st	2nd	3rd	1st	2nd	3rd	4th	1st	2nd	1st	2nd	3rd	4th
Time before fall when events occurred (s)															
5	↔↔	↔	↓↓ ↔↔ LOB	Gear ↑↑	↔ ∩	∩∩	↓↓ ↔↔ ∩∩	↑↑		↑∩		↔ ∩∩ LOB		LOB	↑↑
4			↑↑	LOB LOB ∩∩	LOB ↔↔	Gear ↔↔ ∩ LOB	↓	↔		↓↔ ∩∩	∩	↔	LOB	↓	↔↔
3	↑↑	LOB ↔↔	∩∩	∩ LOB	∩∩	↓	∩	↔↔ ∩∩				↔	↔		↔↔
2	LOB		↑∩ LOB	↑	∩	↑	↑	LOB ↑	↓↓ LOB	↔↔ ∩	↔↔ ∩∩	LOB	↓ ∩∩ LOB	↔ LOB	↔
1	LOB	LOB ↔↔	↔ LOB ↑↑	↑↑↔	↑ ↔	LOB ↓↓		↑↑∩	↓∩∩	LOB	↔ LOB	↑↑ Slide Gear	↑∩	LOB	↑

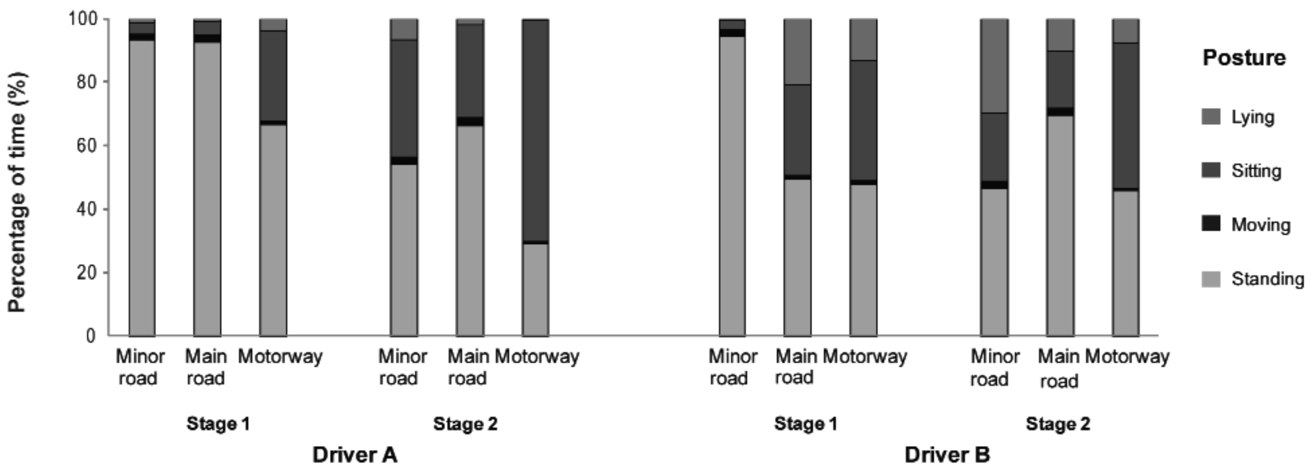
MOV = move; LOB = loss of balance; ↑ = acceleration > 0 to 0.1 g; ↑↑ = acceleration > 0.1 to 0.5 g; ↓ = braking > 0 to 0.1 g; ↓↓ = braking > 0.1 to 0.5 g; ↔ = cornering > 0 to 0.1 g; ↔↔ = cornering > 0.1 to 0.5 g; ↔↔↔ = cornering > 0.5 to 2 g; ∩ = vertical > 0 to 0.1 g; ∩∩ = vertical > 0.1 to 0.5 g; Gear = gear change.

Table 7(b) Sequence of events 5 s before a fall in calves.

Journey number							6							
Fall by focal animal	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th
Time before fall when events occurred (s)														
5	↔↔ ∩∩	∩		↔↔ Gear			↑↑	Gear ↔↔		↔↔↔				↑ ↔↔ ∩∩
4	∩	↑↑	↑∩	LOB	↑↑	LOB			∩	↓	↑↑ Gear	LOB ∩∩	↑↑	∩
3	LOB	∩∩ ↑		Slide	↑		LOB ↑ ↔↔ ∩∩	LOB ↓	LOB	LOB ↑↑ ↔↔	↔↔ ∩∩ LOB	LOB ↓	Gear	↓ ∩∩ LOB
2	↓ ∩∩	↔↔	↑↑ ↔	↔	↔	Gear	Slide ∩	↑	↑	∩	LOB ↓	∩		
1	↓↓∩	↓↓	↔ LOB Gear		Slide	↑ LOB	↑↑	LOB Gear	↓	LOB		↑ LOB	↓ LOB	LOB

MOV = move; LOB = loss of balance; ↑ = acceleration > 0 to 0.1 g; ↑↑ = acceleration > 0.1 to 0.5 g; ↓ = braking > 0 to 0.1 g; ↓↓ = braking > 0.1 to 0.5 g; ↔ = cornering > 0 to 0.1 g; ↔↔ = cornering > 0.1 to 0.5 g; ↔↔↔ = cornering > 0.5 to 2 g; ∩ = vertical > 0 to 0.1 g; ∩∩ = vertical > 0.1 to 0.5 g; Gear = gear change.

Figure 3



Effect of driver, journey stage and road type on the posture of pigs.

Effects of driver, journey stage and road type on behaviour

Cattle

Cattle stood still for most of the journey and no focal animal lay down (rarely a non-focal animal lay down briefly). There was a Road × Stage interaction ($P < 0.01$) in that the effect of the type of road was not consistent between Stage 1 and Stage 2. However, the mean time spent standing still, only varied between 98 and 100% within each section of the journey. There was a Driver × Road × Stage interaction ($P < 0.001$) on the frequency of losses of balance by cattle. For both drivers, the fewest losses of balance occurred during the motorway sections (between 30 and 64 events per h, compared with between 170 and 185 events per h for minor roads). For Driver B, during Stage 1, the frequency of losses of balance on main roads (175 events per h) was lower than that on minor roads (285 events per h), but during Stage 2 the frequency on main roads (244 events per h) was greater than that on minor roads (170 events per h). However, the main overall effect was that the frequency of losses of balance was five times greater on both minor and main roads than on the motorway (95% CI 3–7).

Acceleration, braking, cornering, vertical acceleration and gear changes preceded losses of balance (Table 3). There were no longitudinal and vertical acceleration events (shocks) > 0.5 g in the 5 s period preceding a loss of balance. However, lateral acceleration > 0.5 g preceded 1% of losses of balance. Except for braking (where the percentage was lower), the percentages of losses of balance preceded by shocks between > 0.1 and 0.5 g were similar to those that were preceded by shocks between > 0 and 0.1 g. The driving events that preceded the highest percentage of losses of balance were cornering, followed by acceleration, braking, vertical acceleration and gear changes. The number of slides observed in one focal animal on each journey was 4, 0, 8, 8, 6 and 11. No falls or slides were observed in a focal animal on the motorway. However, there was a Driver × Stage interaction ($P < 0.001$) on the frequency of slides during the minor and main road sections. For Driver B, on average there were 5 slides per h during Stage 1, but only 3 slides per h during Stage 2. Cornering (between > 0 and 0.5 g), acceleration (between > 0 and 0.5 g), braking (between > 0 and 0.1 g), vertical acceleration (between > 0 and 0.5 g) and gear changes preceded between 25 and 54% of the slides (Table 4). The number of falls was too small to examine statistically. An example of the longitudinal, lateral and vertical acceleration recordings, vehicle speed and cattle behaviour before and after a fall is shown in Figure 2. The number of falls observed in one focal animal on each journey was 0, 2, 1, 3, 8 and 0. Out of the 14 falls observed, cornering between > 0.1 and 0.5 g preceded 71% of the falls, acceleration (between > 0 and 0.5 g), braking (between > 0 and 0.1 g), vertical acceleration (between > 0 and 0.5 g) and cornering (between > 0 and 0.1 g) preceded between 14 and 57% of the falls (Table 5). The sequence of events preceding each of these falls is shown in Table 6. Each of the falls was preceded by a series of events that were not consistent between each fall.

Calves

There was a Stage effect ($P < 0.05$) on the percentage of time that calves spent standing still. During Stage 1, they stood still for 95 (± 2.4)% of the time whereas during Stage 2, they stood still for 87 (± 2.4)% of the time. Although there was a Road × Stage interaction ($P < 0.01$), the percentage of time spent moving was small. There was a Stage effect ($P < 0.05$) on the percentage of time that calves spent lying down. During Stage 1, they lay down for 5 (± 2.4)% of the time whereas during Stage 2, they lay down for 12 (± 2.4)% of the time.

There was a Driver × Road × Stage interaction ($P < 0.001$) on the frequency of losses of balance by calves. During

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Table 8 Sequence of events 5 s before a fall in pigs.

Journey number	1			2		4		5			6	
Fall by focal animal	1st	2nd	3rd	1st	2nd	1st	2nd	1st	2nd	3rd	1st	2nd
Time before fall when events occurred (s)												
5	LOB	↑↑∩ LOB			↔↔	↔↔	↓↓	↓↓	∩	↓↓∩	↑LOB Slide	↓LOB
4	↑↑	∩∩	LOB	∩		∩∩	↔ ∩∩		↔↔	↔	↑↑↔↔	
3			LOB ↓	↓↓∩∩		LOB ∩		Gear ↔		↔↔		↑LOB
2	↔ LOB		↓↓ ↔↔↔		↑↑↔↔ LOB	↔	↔↔ ∩		↔ ∩∩ LOB	LOB	LOB	↓
1	Gear	LOB ∩	LOB	LOB	LOB	↔↔	↑↔		↓↓ ↔↔ ∩	↓ ↔	∩∩	↔↔ LOB

MOV = move; LOB = loss of balance; ↑ = acceleration > 0 to 0.1 g; ↑↑ = acceleration > 0.1 to 0.5 g; ↓ = braking > 0 to 0.1 g; ↓↓ = braking > 0.1 to 0.5 g; ↔ = cornering > 0 to 0.1 g; ↔↔ = cornering > 0.1 to 0.5 g; ↔↔↔ = cornering > 0.5 to 2 g; ∩ = vertical > 0 to 0.1 g; ∩∩ = vertical > 0.1 to 0.5 g; Gear = gear change.

Stage 2, the calves were twice (95% CI 2–2) as likely to lose their balance, when driven by Driver A as when driven by Driver B. The calves were twice (95% CI 2–3) as likely to lose their balance on minor roads than on the motorway and twice (95% CI for Driver A 2–2 and for Driver B 2–3) as likely to lose their balance on main roads than on the motorway. When driven by Driver B, the calves were more likely to lose their balance during Stage 1 than Stage 2; twice (95% CI 2–2) as likely on minor roads and 1.3 times (95% CI 1.1–1.4) more likely on main roads.

There were no acceleration or braking events > 0.5 g in the 5 s period preceding a loss of balance. However, lateral acceleration > 0.5 g preceded 1% of losses of balance and vertical acceleration > 0.5 g preceded one loss of balance (Table 3). Except for braking, where the percentage was lower, the percentages of losses of balance preceded by shocks between > 0.1 and 0.5 g were similar to those that were preceded by shocks between > 0 and 0.1 g. The driving events that preceded the highest percentage of losses of balance were cornering, followed by acceleration, vertical acceleration, braking, and gear changes. The number of falls and the number of slides were too small to examine statistically. The number of slides observed in one focal animal on each journey was 4, 0, 8, 8, 6 and 11. No falls or slides occurred on the motorway. Cornering (between > 0 and 0.5 g), acceleration (between > 0 and 0.5 g), braking (between > 0 and 0.1 g), vertical acceleration (between > 0 and 0.5 g) and gear changes preceded between 22 and 38% of the slides (Table 4). Eight percent of the slides were preceded by cornering (between > 0.5 and 2 g) and by braking (between > 0.1 and 0.5 g). The number of falls observed in one focal animal on each journey was 2, 3, 4, 2, 4 and 14. Out of the 29 falls observed, acceleration (between > 0 and 0.5 g), braking (between > 0 and 0.1 g), cornering (between > 0 and 0.5 g), vertical acceleration (between > 0 and 0.5 g) and gear changes preceded between 31 and 62% of the falls (Table 5). The sequence of events preceding each of these falls is shown in Tables 7(a) and (b). Each of the falls was preceded by a series of events that were not consistent between each fall.

Pigs

The effects of driver, journey stage and road type on the posture of pigs is shown in Figure 3. There was a Road × Stage interaction ($P < 0.05$) on the percentage of time within each section that the pigs were standing still. In Stage 1, the percentage of time spent standing still when on minor roads (94 [± 10]%) was significantly greater than when on main roads (71 [± 10.1]%) ($P < 0.01$) and significantly greater than when on the motorway (57 [± 10.1]%) ($P < 0.05$). In Stage 2, the percentage of time spent standing still when on minor roads (50 [± 10.1]%) was significantly greater than when on the motorway (37 [± 10.1]%) ($P < 0.01$). The percentage of time spent standing still when on minor roads was significantly greater during Stage 1 than during Stage 2 ($P < 0.001$). There was a significant effect of road type on the percentage of time spent moving ($P < 0.01$); it was greater when on minor roads (2 [± 0.4]%) than when on the motorway (1 [± 0.4]%) ($P < 0.01$) and greater when on main roads (2 [± 0.4]%) than when on the motorway ($P < 0.05$).

There was a Driver × Road × Stage interaction on the percentage of time spent sitting ($P < 0.05$). For Driver A, during Stage 2, the percentage of time spent sitting was greater when on the motorway (69 [± 11.5]%) than when on minor roads (36 [± 11.5]%) ($P < 0.05$) or when on main roads (29 [± 11.5]%) ($P < 0.01$). For Driver B, during Stage 1, the percentage of time spent sitting was greater when on the motorway (38 [± 11.5]%) than when on minor roads (3 [± 11.5]%) ($P < 0.05$). For Driver A, the percentage of time spent sitting when on minor roads during Stage 2 (36 [± 11.5]%) was significantly greater than during Stage 1 (4 [± 11.5]%) ($P < 0.05$) and when on the motorway during Stage 2 (69 [± 11.5]%) it was significantly greater than during Stage 1 (28 [± 11.5]%) ($P < 0.01$). Less than 1% of the time was spent kneeling down.

There was a Driver × Road × Stage interaction on the percentage of time spent lying down ($P < 0.01$). For Driver B, the percentage of time spent lying down during Stage 1 was greater when on main roads (21 [± 6.9]%) than when on minor roads (0.2 [± 6.9]%) ($P < 0.001$), but during Stage 2 it was greater when on minor roads (29 [± 6.9]%) than when on main roads (10 [± 6.9]%) ($P < 0.01$). For Driver B, the percentage of time spent lying down during Stage 1 was greater when on the motorway (13 [± 6.9]%) than when on minor roads (0.2 [± 6.9]) ($P < 0.05$), but during Stage 2 it was greater when on minor roads (29 [± 6.9]%) than when on the motorway (8 [± 6.9]%) ($P < 0.001$). For Driver B, the percentage of time spent lying down, when on minor roads, was greater during Stage 2 (29 [± 6.9]%) than during Stage 1 (0.2 [± 6.9]%) ($P < 0.001$).

There were Driver × Stage ($P < 0.05$) and Road × Stage ($P < 0.01$) interactions on the frequency of losses of balance by pigs. During Stage 1, losses of balance were twice as likely when the vehicle was driven by Driver A than when driven by Driver B (95% CI 1.5–3). During both stages, losses of balance were twice as likely when the vehicle was driven on main roads than when driven on the motorway (95% CI 1.9–2.3) and twice as likely when the vehicle was driven on minor roads than when driven on the motorway (95% CI 1.9–3.6).

The contribution of each driving event preceding a loss of balance in pigs was similar in magnitude to that found in calves (Table 3). Although for cattle and calves, each loss of balance occurred during a standing posture, in pigs, some losses of balance occurred when the pig was sitting down. The number of falls and the number of slides were too small to examine statistically. The number of slides observed in a focal animal on each of the journeys was 7, 6, 7, 17, 1 and 2. No falls or slides occurred on the motorway. Cornering (between > 0 and 0.5 g), acceleration (between > 0 and 0.5 g), braking (between > 0 and 0.5 g), vertical acceleration (between > 0 and 0.5 g) and gear changes preceded between 20 and 54% of the slides (Table 4). One slide was preceded by a corner between > 0.5 and 2 g. The number of falls observed in a focal animal on each of the journeys was 3, 2, 0, 2, 3 and 2. Out of the 12 falls observed, acceleration (between > 0.1 and 0.5 g), braking (between > 0.1 and 0.5 g), cornering (between > 0 and 0.5 g) and vertical acceleration (between > 0 and 0.5 g) preceded between 33 and 58% of the falls (Table 5). The sequence of events preceding each of these falls is shown in Table 8. Each of the falls was preceded by a series of events that were not consistent between each fall.

Discussion

The observation that cattle stood still for most of the journey and did not lie down was consistent with previous reports from observations of journeys of at least this duration (Warriss *et al* 1995; Knowles *et al* 1999). However, Kent and Ewbank (1983) did report that cattle of similar live weight to that used in the current study did lie down for about 6% of a 6–6.5 h journey, especially when driven on a motorway. The frequency of losses of balance observed in cattle in the current study was considerably greater than that reported in previous studies (Kenny & Tarrant 1987a,b; Tarrant *et al* 1988, 1992). This was most likely due to differences in the recording of what constituted a loss of balance and/or differences in the journey characteristics (eg driving style, type of flooring and use of bedding), rather than to an effect of stocking density. Although not examined in this study, there are interesting interactions between stocking density during transport and losses of balance experienced by cattle that can affect the frequency of losses of balance and falls. For example, Tarrant *et al* (1988) observed more losses of balance at a stocking density of about 581 kg m^{-2} than at 312 kg m^{-2} (similar to the stocking density used in the current study). In 30 cattle, transported for 4 h at the lower stocking density, only two falls were recorded, whereas in 54 steers transported for the same duration, but at the higher stocking density, 45 falls were recorded. In another study, Tarrant *et al* (1992) observed fewer losses of balance, but more falls, at a stocking density of about 584 kg m^{-2} than one at about 448 kg m^{-2}.

The space allowances provided for each type of animal in this study was similar to space allowances for their live weight recommended by Warriss (1998) for pigs and by the equation provided by Petherick and Phillips (2009) for cattle, and was similar to the lower space allowance treatment used by Grigor *et al* (2001) for calves. Although Petherick and Phillips (2009) reviewed the information on space allowance during transportation, the relationship between space allowance and the risk of injury from loss of stability is still not clear. For cattle, Tarrant *et al* (1988) showed that at very low space allowance, cattle were more likely to fall, then have difficulty regaining a standing posture and were at risk of trampling by other animals. For sheep, Jones *et al* (2010) showed that if sheep have sufficient space they could spread their feet to maintain balance in response to vehicle motion easier than they could if they were at a lower space allowance. Barton-Gade and Christensen (1998) described pigs transported at a low space allowance as standing together to provide mutual support against vehicle motion, but when provided with more space the pigs had difficulty keeping their balance when the vehicle negotiated bends or uneven road surfaces. However, if the pigs were provided with adequate space they would sit or lie down to avoid difficulty maintaining their balance in response to vehicle motion.

Kenny and Tarrant (1987a,b) and Tarrant *et al* (1988, 1992) were able to identify specific driving events such as cornering, braking, gear changing and rough surfaces as the most likely cause of losses of balance observed in cattle. They noted that maintenance of stability was more difficult if the cattle had to deal with two different events at the same time. In the current study, other than the addition of recordings of longitudinal acceleration (arising from increases in vehicle speed) that preceded many losses of balance and falls, the current study confirms this previous work. The observation that a driving event occurred during the 5 s before a loss of stability does not necessarily mean that the driving event caused the loss of stability; it only suggests that it might have been a factor. Some shocks, especially those of lower magnitude (eg < 0.1 g) occurred frequently and therefore they were likely to have been present in the period before a loss of stability and may not have had any influence on the subsequent loss of stability. One potential risk factor for a loss of stability that was occasionally observed but not quantified, were interactions between animals where the movement of one animal lifted a leg of another animal, thereby making that animal more vulnerable to a loss of stability. Although the potential consequences of rapid braking or changing of lane (for example to avoid a road traffic accident) are greater, in this study the greater vehicle speed on motorways (compared with that on minor and main roads) was relatively constant and this higher speed did not result in more losses of stability or disturbance to rest. With the exception of one fall, the sequence of events that preceded a fall by cattle consisted of several different types of driving events. As no specific driving event caused a fall, this implies that attention needs to be given to all aspects of driving, such as route selection, speed on minor and main roads and anticipation of driving events, such as corners, to reduce the severity of driving events on the animals. In the current study, the driving style appeared to be similar between drivers and few consistent differences in the behaviour of the animals were observed between journeys driven by the two drivers.

Although the calves spent most of their time standing still, they did lie down for 5% of the time during the first 3 h of the journey and for a longer time (12%) during the final 3 h of the journey. This increase in lying with journey duration is consistent with previous studies (Kent & Ewbank 1986; Knowles *et al* 1999; Grigor *et al* 2001). However, because these journeys were longer than 6 h, the percentage of time spent lying down during the journey was longer than in the current study. At the lower space allowance used by Grigor *et al* (2001), the percentage of time spent lying down during a 9-h journey was between 22 and 34%. The frequency of losses of balance recorded by Grigor *et al* (2001) was considerably lower than that recorded in the current study. These differences may have been due to more time spent on smoother roads with fewer road features (main road with dual carriageway) in the study by Grigor *et al* (2001) than was the case in the current study. Although there were interactions between road type and both driver and journey stage, in general, the frequency of losses of balance was lower when on the motorway compared with minor roads and although there was no significant effect of road type, the percentage of time spent lying down was numerically higher when on motorways (13%) than on the main and minor roads. There was considerable variation between journeys in the number of falls by calves.

In the current study, pigs were observed to stand, lie and sit down. Their posture was affected by road type, journey stage and to a lesser extent by differences between the driving characteristics of the two drivers. Barton-Gade (2008) observed that the main resting behaviour of pigs during most of a 3-h journey was sitting down and lying was only observed in some of the pigs towards the end of the journey. Whereas in another study some pigs either sat down or lay down within the first 2 h of a journey (Lambooy *et al* 1985). The results of the current study are consistent with the above and provide the following additional information. In general, there was more standing and moving behaviour on minor roads than on the motorway and when on the motorway there was more standing during the early part of the journey than during the later part. There was more sitting when the vehicle was driven on the motorway than on minor roads and for one driver, there was more sitting during the later part of the journey than the earlier part. For one driver, during the early stages of the journey, there was more lying when the vehicle was driven on the motorway than on minor roads, and on minor roads there was more lying during the later part of the journey than the earlier part.

Although not examined in this study, Barton-Gade and Christensen (1998) observed an effect of space allowance on both the resting behaviour and the ability of pigs to maintain balance in response to driving events. At a space allowance of 0.42 m^2 for a 101-kg pig (in the current study the space allowance was equivalent to 0.45 m^2 for a 111-kg pig), all of the pigs were observed to stand and to have 'difficulty keeping their balance when the vehicle negotiated bends or uneven road surfaces'. At a higher space allowance of 0.50 m^2 per pig, the pigs were reported to still have 'difficulty keeping their balance when the vehicle negotiated bends', but about 20% of the pigs sat down. At a lower space allowance of 0.39 m^2 per pig, postural changes were frequent with 60–80% standing during the early part of the journey, the rest were sitting or lying down and after 50 min, 14% were standing, 29% sitting and 57% lying. This effect of journey duration was also seen in the current study and was reported by Lambooy and Engel (1991). In their study, conducted at a similar stocking density (expressed in kg m^{-2}) to that used in the current study, the percentage of pigs lying down increased during the first 3 h of the journey to 30–50%.

The quality of the journey can also affect resting behaviour and rough journeys (with acceleration events > 0.7 g) can be stressful (Bradshaw *et al* 1996b) and aversive to pigs (Stephens *et al* 1985). In addition, Randall and Bradshaw (1998) measured more longitudinal, lateral and vertical acceleration when pigs were driven on minor roads compared with motorways and some pigs showed foaming at the mouth or chomping, which the authors considered might have been associated with travel sickness on minor roads. Bradshaw *et al* (1996a) reported that during a 40-min journey, pigs spent more time lying down during a 'smooth' journey (characterised by an accelerometer) than they did when a journey was characterised as 'rough'. Peeters *et al* (2008) observed that pigs (about 106 kg) on a short journey (63 km at a space allowance of 0.62 m^2 per pig) laid down for about 13% of the time when a livestock trailer towed by a vehicle was driven carefully, but only laid down for about 3% of the time when the trailer was driven at a faster speed that caused a higher integrated recording from three axes of acceleration (expressed in terms of a comfort value for humans). However, no relationship between lying behaviour and this calculated acceleration value was found when each axis was examined separately. Peeters *et al* (2008) did not find a relationship between the percentage of time that the pigs were observed sitting and the acceleration values (either integrated for all three axes or considered separately). When the trailer was driven carefully, the percentage of pigs sitting down was 0.7%, whereas when the trailer was driven at a higher speed it was 2.7%. There was no significant difference between drivers, that were each asked to drive according to three categories of driving style (carefully, normal and fast), on the posture of the pigs. There was no effect of driving style on the integrated recording from the vertical axis of acceleration. These authors considered that although a faster speed would have increased the overall vibration, vertical accelerations may have been reduced by the trailer suspension, whereas the speed would have increased longitudinal and lateral acceleration recordings. However, the type of effect is likely to vary with vehicle type. For example, Gebresenbet *et al* (2011) found that when a cattle truck with an air suspension system was driven on a tarmac road, the vertical acceleration increased with the speed with which the vehicle was driven.

In the current study, shocks with a magnitude > 0.1 g were recorded in all three axes and some shocks from lateral acceleration and vertical acceleration were between > 0.5 and 2 g. These shocks were similar in magnitude to those recorded in a vehicle driven on surfaced roads during the transportation of cattle by Wikner *et al* (2003) and pigs by Bradshaw *et al* (1996b). Although, the magnitude of the mean background floor vibration recorded by Gebresenbet *et al* (2011) in each acceleration axis in a cattle truck was less than 0.1 g, the highest longitudinal acceleration experienced by the cattle (0.23 g) was recorded when that vehicle was driven on gravel roads at speeds of 50 and 70 kph. The influence of road surface was also shown by Wikner *et al* (2003) who recorded higher vertical acceleration values when a vehicle containing cattle was driven on gravel roads (± 4 g) than when it was driven on surfaced roads (± 2.2 g). Differences in acceleration values between studies are due to the way in which the acceleration recordings in each axis were calculated and possibly due to differences between vehicle characteristics and road types. The work by Gebresenbet *et al* (2011) suggests that, in the current study, it was likely that the vehicle shocks were transmitted to the animals and were likely to have caused some of the losses of stability observed.

Video recordings, a vehicle tri-axial accelerometer and GPS system provided an effective means for assessing the effects of driving events on two aspects of the welfare of cattle, young calves and pigs during transportation; namely their stability and resting behaviour.

Animal welfare implications

During road transportation, driving events (such as acceleration, braking and rough surfaces) caused longitudinal, lateral and vertical acceleration events which required cattle, young calves and pigs to make frequent postural adjustments to maintain stability. Although not examined in this study, this frequent movement has the potential to cause stress and fatigue through continual movements and a reduced ability to rest. The frequency with which the animals experienced losses of balance was markedly affected by road type. When the vehicle was driven on a motorway compared with a minor or main road, there were fewer road features that required adjustments by the driver and the frequency of shocks was lower. This smoother journey on a motorway also caused less disturbance to resting behaviour. Although infrequent, falls were observed in cattle, calves and pigs. Falls have the potential to cause injury and stress. Some individual animals appeared to be more susceptible to falls than others and experienced repeated falls during a journey. As falls occurred after a series of different types of events rather than after one or two specific driving events, this implies that attention needs to be given to all aspects of driving, such as speed, route selection and anticipation of driving events, such as corners. A driver-training DVD was produced from this study to demonstrate the importance of an awareness of the implications of driving events on the animals transported in the livestock compartment. A copy of this DVD can be obtained from the authors.

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