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Animal Welfare 2011, 20: 263-269
ISSN 0962-7286

Luminance and glare in indoor cattle-handling facilities

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Abstract

This study examined the sources of glare and range in luminance levels in eleven UK cattle abattoirs, and the effect of reflected glare from a footbath on balking behaviour of cows in a milking parlour. At the abattoirs, the mean luminance levels decreased from 240,000 cd m^{-2} outdoors to 100 cd m^{-2} in the stunning pen. In five of the abattoirs, the luminance of the glare from wet floor surfaces was three times higher than the luminance from the surrounding darker areas, and the luminance of the glare from shiny metal surfaces was ten times higher than the luminance from the adjacent darker areas. In the glare study, frequency of balking increased significantly from 10 to 23% when reflected glare increased from 0 (no lightbulb) to 873 cd m^{-2} (100 W bulb), but significantly fewer animals balked during the afternoon milking than at the morning milking times.

Keywords: *abattoir, animal welfare, balking, cattle, floor, glare*

Introduction

Most research into the effects of brightness and glare has focused on people rather than animals, and highlights problems such as driving at night, prolonged exposure to bright sunlight and working conditions in offices. (Aslam *et al* 2007; Gray & Regan 2007). In human visual acuity, object contrast, accommodation, brightness discrimination and motion perception are affected by glare. Some of these effects rely on stray light obscuring the fovea. Since cattle do not possess a fovea it is not quite clear which of the above effects occur in dairy cattle (Phillips *et al* 2000). Some scientists found that cattle are less susceptible to glare than humans, and that humans are able to distinguish smaller differences in light intensities than calves. The lowest level for object discrimination is found to be 2 lux (Phillips & Weiguo 1991; Phillips & Lomas 2001). It is generally recognised that moving cattle in unfamiliar indoor surroundings can be difficult if they are required to pass from a well-lit to a darker area (Grandin 1996). A study conducted by Cross *et al* (2008) showed that horses were significantly more reluctant to move from a well-lit loading arena onto a trailer than from a dark loading arena. They also seemed to require more environmental exploration when leaving the lit loading arena to load onto a dark trailer. Behaviours horses expressed when moving from a lit arena to a lit trailer were interpreted as response to glare the horses experienced from the high intensity halogen lamps. Anecdotal observations lead to the conclusion that cattle are more inclined to move towards well-lit rather than dark areas; they may hesitate or even refuse to enter the dark areas. However, light that results in glare may also cause the animals to balk, which can be disruptive to handling (Grandin 1997, 1999). Despite these well-explained effects, there is limited information on the light intensities that exist in livestock handling facilities, and on situations that cause glare. According to Grandin (1999), the ideal illumination for moving cattle inside a building "should resemble a bright cloudy day", but more precise information is lacking.

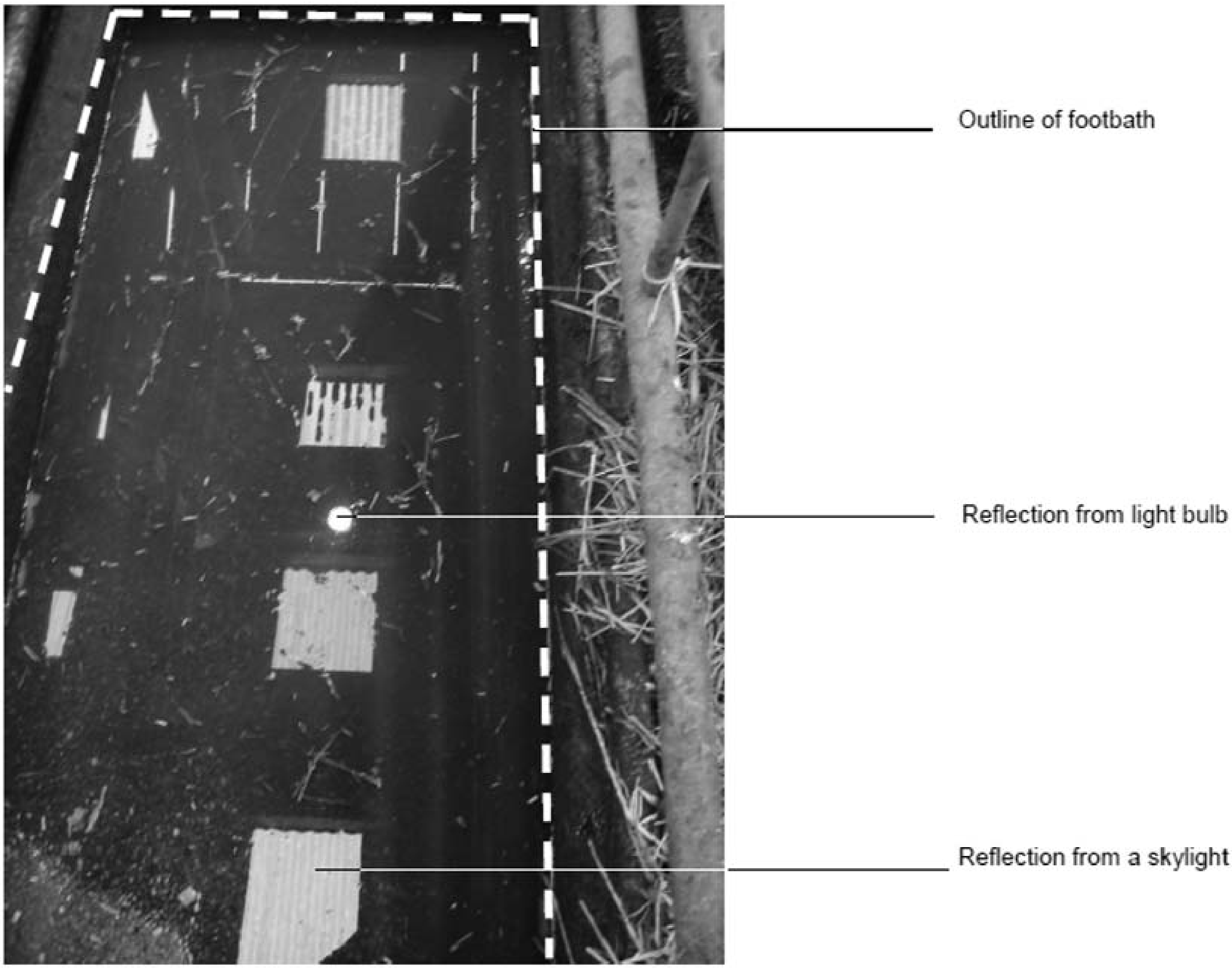
The objectives of this study were to assess changes in luminance within beef abattoirs in the United Kingdom (UK), and to evaluate the luminance intensity in a glare situation that can lead to balking in cattle using a dairy herd. It is proposed that this background information will be useful in planning further work, which defines the optimum lighting intensities to aid the movement of cattle within buildings, and the sensitivity of cattle to glare situations.

Materials and methods

Abattoir luminance measurements

Luminance measurements were obtained from the walls and floors of eleven beef abattoirs. All measurements were made during daylight hours by the same person at eye level using an LS-110 Minolta Luminance Meter (Konica Minolta Sensing Inc, Aichi, Japan). Each facility was assessed for individual glare spots by walking the same route cattle took from unloading to the stun box.

Figure 1



Reflections of four translucent corrugated skylight panels and an incandescent lightbulb in a water-filled footbath (200 × 84 cm; length × width) placed at the end of a cattle race near the exit of a milking parlour.

Where possible, luminance readings were obtained from ten sites at each abattoir, including the sky (measured outdoors), skylights in the lairage roof, lighting in the lairage, sheet metal partitions, and floors. The recording area for each of these sites was selected by visual appraisal as being representative of the facility, but within each area the selected surface was scanned using the luminance meter for the patch with the highest luminance value. In addition, five abattoirs had potential sources of glare, such as wet floors (n = 12) or metal surfaces (n = 20), and luminance measurements were obtained from each of these together with measurements from a non-glare surface of the same material adjacent to the glare patch. The measurements were also taken at eye level using the LS-110 Minolta Luminance Meter.

Glare study

Two glare situations were created at a dairy farm; in the first instance, natural daylight from translucent corrugated skylight panels in the roof was allowed to reflect off the surface of a water-filled footbath located at the end of a cattle race. The footbath measured 200 × 84 cm (length × width) and had a concrete sill to contain the water. An additional glare situation was created by suspending an incandescent lightbulb 232 cm above the footbath (Figure 1). The bulb was shielded to minimise direct glare.

A dairy herd comprising 93 Holstein Friesian cows was observed during eight consecutive milkings (two per day). At the beginning of every milking, the footbath was filled with water to create a reflective surface. The cows were familiar with the glare resulting from the reflected skylights owing to previous experience during prophylactic and therapeutic foot dipping, but were not accustomed to the glare reflected from the lightbulb. Using the footbath as means to create a reflective surface allowed the creation of novel glare without introducing too many new factors to the animals' everyday life, hence eliminating additional reasons

https://doi.org/10.1017/S0962728600002748 Published online by Cambridge University Press

Figure 2

(a) (b)

Cows in the race demonstrating the behaviours (a) 'Looked' (ie the animal moved with its head directed towards a potential glare source or other point of interest) and (b) 'Stopped' (ie, the animal stopped for 10 s or longer in the race).

(ie wet patch of floor in an unusual area, different material with novel smell, etc) for balking at the point of glare. On the first day, no lightbulb was used (control) but on days two, three and four, a 40, 60 and 100 W light bulb, respectively, was suspended above the footbath,. Each animal was observed as it moved through the race containing the footbath and its behaviour and any required human interference recorded as one of the following:

• Walked — the animal moved without obviously focusing on the footbath or stopping at any point;

• Followed — the animal followed another animal through the race at a distance of less than 1 m;

• Looked — the animal moved with its head directed towards a potential glare source or other point of interest (Figure 2[a]);

• Stopped — the animal stopped for 10 s or longer in the race (Figure 2[b]);

• Moved on — the animal stopped at some point in the corridor but moved on without external motivation by an attendant;

• Voice — the animal stopped at some point and had to be vocally encouraged to move on by an attendant;

• Contact — the animal stopped at some point and had to be touched by an attendant to be encouraged to move on;

Light off — the animal would only walk through the corridor when the lightbulb was switched off; and

• Balking — includes the behaviours, 'stopped', 'moved on', 'voice', 'contact' and' light off' and did not include 'looked'.

In addition, the luminance of both the ambient and reflected light within the glare patches in the footbath were measured every 30 mins at eye level by the same person standing in the same spot facing the same direction resulting in a total of 175 footbath luminance measurements. The luminance of a non-glare patch adjacent to a glare measurement was also recorded to give a light:dark contrast measurement.

The plan was that if at any time a cow displayed obvious signs of distress from the modified lighting situation, the trial would be discontinued. If a cow refused to move over the glare patch on the floor, it was gently coerced to move by approaching from behind, and if that failed, the light was temporarily switched off to allow the cow to pass. The level of light normally used in the corridor was sufficient for the animals to find their way from the parlour. The corridor was the same as that normally used by the animals when returning to their pens after milking in the parlour. The same ambient lighting (daylight through skylights plus fluorescent strip lighting) was present throughout the course of the project.

Statistical analysis

Descriptive statistics were obtained for all continuous variables and the Kolmogorov-Smirnov test was used to determine whether or not each variable was normally distributed. The Mann-Whitney U test was used to identify which of the continuous variables differed significantly between animals that balked and those that did not. A Chi-square test was used to determine whether frequency of balking was significantly associated with the wattage of the lightbulb or the time of day. Only variables with a P-value of 0.2 in the univariable analysis

Table 1 Mean (± SEM) and range of luminance measurements (cd m⁻²) for ten different light sources in eleven cattle abattoirs in the UK. All measurements were obtained during daylight hours using an LS-110 Minolta Luminance Meter.

Source	Number of abattoirs	Luminance (cd m^{-2})	Luminance range (cd m^{-2})
Sky	11	239,943 (± 76,452)[a]	10,020–768,200
Filament lightbulb	3	91,209 (± 44,384)[ace]	7,326–158,300
Skylight	4	76,105 (± 72,533)[abcd]	2,931–293,700
Fluorescent striplight	9	5,037 (± 824)[b]	32–10,220
Unloading area floor	11	3,819 (± 1,025)[b]	151–9,796
Metal objects	6	662 (± 493)[cf]	7–3,084
Raceway floor	11	270 (± 160)[df]	1–1,554
Stunning pen floor	11	102 (± 68)[df]	1–749
Lairage floor	11	87 (± 30)[def]	5–282
Crush floor	6	64 (± 24)[def]	1–127

Means without a common superscript differed significantly at $P < 0.05$.

were included in the subsequent multivariable analysis. In order to account for the potentially correlated data resulting from multiple observations on the same cow, a mixed-effects logistic regression model, with cow as a random effect, was initially used to identify the variables significantly associated with balking. However, as there was no significant difference between the results of the mixed-effects logistic regression model and those of a binomial logistic regression model (indicating no intra-cow clustering), the results of the binomial logistic regression model were used. In all instances, a *P*-value of 0.05 was considered to indicate statistical significance. All analyses were performed using SPSS 16.0 for Windows (SPSS Inc, Chicago, IL, USA), except for the mixed-effects model, which was performed using Stata 9.0 for Windows (StataCorp LP, USA).

Results

Abattoir luminance measurements

Of the ten different sources (Table 1) from which luminance was obtained, the outdoor sky reading had the highest mean luminance. The brightest sources of indoor-light were filament light bulbs, followed by skylights and fluorescent striplights. The brightest reflected light surfaces were in the unloading area, which was outdoors. Within the lairage, the brightest source of reflected light was sheet metal or supporting posts at gates, doors and raceways. The floors were not usually a source of bright light, but there was considerable variation in their luminance between abattoirs. For wet floor surfaces, the bright regions had a luminance of 159 (± 56) cd m^{-2} and for an adjacent dark region it was 51 (± 40) cd m^{-2} ($P < 0.001$). For metal objects, 20 bright spots had an average luminance of 694 (± 237) cd m^{-2}, and the adjacent dark regions had a mean luminance of 65 (± 27) cd m^{-2} ($P < 0.05$).

Glare study

The mean luminance measurements of the direct and reflected sources of light in the study are presented in Table 2. There was a significant positive correlation between wattage and reflected glare of the bulb ($r^2 = 0.98$; $P < 0.01$) and between the luminance and reflected glare of the skylight ($r^2 = 0.76$; $P < 0.01$).

For animals that balked, the mean luminance of the non-glare region was significantly lower and mean luminance of the lightbulb reflection was significantly higher, than for animals that did not balk (Table 3). In addition, mean luminance of the lightbulb was marginally significantly higher for animals that balked compared with those that did not (Table 3). However, mean luminance from both the skylight and its reflection did not differ significantly between animals that balked and those that did not.

The proportion of cows which looked at the footbath increased significantly as the reflected glare increased ($P < 0.05$; Table 4); more than twice as many animals balked (stopped + coercion with the introduction of reflected glare at 213 cd m^{-2}. There was also a significant association between time of day and the proportion of animals that balked ($\chi^2 = 20.4$, df = 3; $P < 0.001$); approximately three times more animals balked at 0530 and 0630h, and approximately twice as many animals balked at 1530 than at 1630h (Table 5).

Multivariable logistic regression found that increased luminance resulted in increased odds of dairy cows balking in the raceway containing a footbath, and that cows were less likely to balk indoors late in the day (Table 6). Cows were more than twice as likely to balk when light was provided by a 40 W bulb (OR 2.58, 95% CI 1.40–4.77) and more than three times as likely to balk when a 100 W bulb was used (OR 3.09, 95% CI 1.68–5.71) than when no lightbulb was used. The likelihood of a cow balking was much lower in the late afternoon (1630h) than at the other three times investigated (OR 0.25, 95% CI 0.13–0.48).

https://doi.org/10.1017/S0962728600002748 Published online by Cambridge University Press

Table 2 Mean (± SEM) and range of luminance measurements (cd m^{-2}) of the direct and reflected sources of light in the glare study.

	Number of observations	Luminance (cd m^{-2})	Luminance range (cd m^{-2})
Sky†	36	6,248 (± 949)	427–20,680
Skylight	36	3,795 (± 906)	232–28,190
Lightbulb: direct			
40 W	2	11,285 (± 5)	11,280–11,290
60 W	2	41,650 (± 3,030)	38,620–44,680
100 W	2	88,725 (± 255)	88,470–88,980
Skylight reflection in the footbath†	36	257 (± 58)	9–1,485
Footbath, non-glare region	36	8 (± 1)	1–39
Lightbulb: reflection			
40 W	9	213 (± 9)	177–262
60 W	9	418 (± 14)	344–469
100 W	9	873 (± 13)	831–932

† Measurements taken between 0530 and 0730h and 1530 and 1700h.

Table 3 Mean (± SEM) luminance of the lightbulb, skylights and their reflections, as well as of the non-glare region of the footbath, for animals that did and did not balk.

Luminance (cd m^{-2})	Balked (n = 137)	Did not balk (n = 578)	*T*-test, *P*-value
Non-glare region of footbath	7 (± 0.6)	9 (± 0.3)	0.004
Lightbulb (actual)	38,170 (± 3,005.3)	31,907 (± 1,445.5)	0.058
Lightbulb (reflection)	432 (± 26.1)	353 (± 13.4)	0.009
Skylight (actual)	4,103 (± 584.6)	4,651 (± 238.7)	0.333
Skylight (reflection)	262 (± 34.4)	315 (± 15.7)	0.144

P-value obtained using an independent *t*-test.

Table 4 Proportion of dairy cows that exhibited different behaviours in response to increasing levels of reflected glare (cd m^{-2}) from overhead lightbulbs when moving through a water-filled footbath.

	No lightbulb	40 W bulb	60 W bulb	100 W bulb
Reflected glare (cd m^{-2})	0	213	418	873
Cow behaviour				
Walked (n[%])	168 (90)	141 (79)	140 (77)	129 (77)
Looked at footbath (n[%])	51 (27)^{a}	58 (33)^{ab}	71 (54)^{b}	86 (51)^{c}
Stopped for ≥ 10 s before passing through the footbath (n[%])	16 (9)^{a}	32 (18)^{b}	39 (21)^{b}	37 (22)^{b}
Coercion (voice, contact, light off) (n[%])	2 (1)^{a}	5 (3)^{a}	4 (2)^{a}	2 (1)^{a}
Total observations	186 (100)	178 (100)	183 (100)	168 (100)

Means in a row without a common superscript differed significantly at $P < 0.05$.

Discussion

Abattoir luminance measurements

This study showed that, during daylight hours, floor luminance within abattoirs decreased as cattle progressed through the abattoir. Some of the lairages were poorly lit, especially as the cattle moved closer to the stunning pen, but there was extensive variation in luminance as seen in the wide range of measurements obtained from the raceway and stunning pen floors (Table 1). Phillips *et al* (2000) conducted a study to assess the influence of various light intensities (0–250 lux) in passageways on the locomotion of dairy cows, and suggested an optimum illumination level for dairy cow locomotion to be between 39 and 119 lux.

Table 5 Number (%) of dairy cows that balked when walking through a footbath at different times of the day.

Time	Total cows (n)	Number that balked (%)
0530h	150	40 (26.7)[a]
0630h	195	47 (24.1)[ab]
1530h	209	36 (17.2)[b]
1630h	161	14 (8.7)[c]

Number that balked without a common superscript letter differed significantly at $P < 0.05$.

Table 6 Variables significantly associated with frequency of balking in dairy cattle in a milking parlour. Variables were identified using a binomial regression model.

Variable	Value	OR	95% CI	*P*-value
Lightbulb	None	–		0.000
	40 W	2.58	140–4.77	
	60 W	2.91	1.60–5.31	
	100 W	3.09	1.68–5.71	
Time	0530h	–		0.002
	0630h	0.88	0.53–1.44	
	1530h	0.56	0.35–0.94	
	1630h	0.25	0.13–0.48	

Though cows are well adapted to low light levels with a high concentration of rods and a *tapetum lucidum*, they showed an increased walking rate in the dark, indicating their aversion to darkness. Cattle movement is not only linked to the intensity of the light but also to the wavelength. Phillips and Lomas (2001) found that cattle are more active and have stronger movements in long wavelength (red) light than in short (blue) or medium (green) wavelength light. The animals performed fewest movements in the medium wavelength light compared with the short and long wavelength lights, which indicated that green light used in abattoirs may benefit cattle handling in this environment. Based on anecdotal experience (Grandin 1996), decreasing luminance near the stunning pen can contribute to increased reluctance to move towards the point of slaughter. Phillips and Arab (1998) conducted an experiment to establish whether individually penned cattle prefer to exhibit certain behaviours in the light or in the dark by enabling the animals to switch lights on and off. There was a weak preference to feed and, to a lesser extent, to stand and lie down in the light. No preference in lighting situation could be observed for behaviours such as sleeping and ruminating. For individually penned animals, the preferences might be slightly different to those of group-housed cattle. Further work is required to establish the extent to which differing luminance within the building contributes to the overall interference of cattle movement in commercial abattoirs, and the effect of other distractions, such as noise, confinement, contrasts in floor surface and unfamiliar surroundings on balking.

Glare and balking

Frequency of balking increased significantly from 10 to 23% when reflected glare increased from 0 (no lightbulb) to 873 cd m^{-2} (100 W bulb). Even a small increase in luminance from 0 (no lightbulb) to 213 cd m^{-2} (40 W bulb) resulted in double the frequency of balking, emphasising the effect that glare from even very low levels of light can have on balking in cattle. However, there appeared to be other factors, such as feed incentives after the afternoon milking at 1630h, which could override the balking effect from the reflected glare (Table 5). In the abattoir study, 25% of the glare measurements for wet floor surfaces had a luminance greater than 380 cd m^{-2}. This, together with the findings from the dairy herd study, highlights the likelihood of cattle balking in abattoirs as a result of glare. In the abattoirs we investigated, metal objects often produced the strongest glare values, supporting the suggestion that they should also be considered potential causes of distraction during stock movement.

Though cattle are known to be less able to resolve visual details than humans (Lomas *et al* 1998), practical experience has shown that localised light contrasts or glare can make animal management difficult, causing them to balk or become alarmed (Grandin 1980, 1997, 2007; Gregory & Bell 1987). Depending on its intensity, glare can affect cattle in three ways. Firstly, in extreme situations, it can lead to impaired vision, such as snow blindness, which in the past has been a problem in cattle grazing in the taiga (Anonymous 1898). In humans, this is classified as a type of disability glare (Hopkinson *et al* 1966). Secondly, it can cause discomfort which in people causes subjects to shield their eyes or avoid exposure to the brightness because of the risk of discomfort. Thirdly, it can cause distractions which hinder animal management. For example, in abattoirs, it can interfere with cattle movement and even cause cattle to refuse to move or go towards the glare (Grandin 1997, 2006). In humans, a luminance intensity of approximately 2,590 cd m^{-2} was found to be the borderline between comfortable and uncomfortable sources of light (Kim *et al* 2009). However, this borderline value depends on the sensitivity of the individual, the luminance intensity of the source plus its solid angle, the background luminance and the position of the glare source in the field of view. Although a similar borderline value is yet to be established for cattle, if the value of 2,590 cd m^{-2} is used as a guideline, the reflected glare experienced by the dairy cows in the present study was always less than this value, while direct glare from the lightbulbs was always at least four times this value. In other words, the reflected glare was not expected to create discomfort, whereas the direct glare from the bulbs had the potential to do so. Since the lightbulbs were shielded to reduce direct glare, and the majority of the cows looked at the reflected glare in the footbath (Table 4), it would appear that the reflected glare was the primary cause of balking in this study, suggesting that cattle either have a much lower borderline value than humans or that they have acute curiosity or distraction towards novel glare sources that are in the comfortable source range.

https://doi.org/10.1017/S0962728600002748 Published online by Cambridge University Press

Animal welfare implications

Abattoirs, livestock markets and milking parlours are areas where an uninterrupted flow of animals is desired. Cattle prefer to move from darker to lighter areas, and good lighting should be provided in all cattle handling facilities. This study showed that cattle are exposed to a wide range of light intensities in abattoirs, and light intensity decreased as they proceeded from the unloading bay to the stunning pen. Glare from wet or reflecting surfaces caused a significant increase in balking. This study also showed that glare produced by light sources of relatively low luminance caused considerable balking in dairy cows leaving a milking parlour. It is therefore important to pay attention to the areas where glare can occur. Puddles on the floor, shiny metal sheeting and any other reflective surface within the field of vision of cattle should be corrected to avoid balking.

Conclusion

Abattoir floors become progressively darker as cattle move towards the stunning point, which may contribute towards the animals' reluctance to move in the required direction. Furthermore, reflected glare from a 40 W lightbulb (213 cd m^{-2}) is sufficient to significantly increase the frequency of balking in a milking parlour.

Acknowledgements

This work was supported by a research grant from the Department for Environment Food and Rural Affairs. The authors would like to thank the abattoir owners and farm staff for their co-operation and support.

References

Anonymous 1898 Spectacles for cattle. *Queensland Agricultural Journal 3*: 323

Aslam TM, Haider D and Murray IJ 2007 Principles of disability glare measurement: an ophthalmological perspective. *Acta Ophthalmologica Scandinavica 85*: 354-360

Cross N, van Doorn F, Versnel C, Cawdell-Smith J and Phillips C 2008 Effects of lighting conditions on the welfare of horses being loaded for transportation. *Journal of Veterinary Behavior 3*: 20-24

Grandin T 1980 Observations on cattle behaviour applied to the design of cattle handling facilities. *Applied Animal Ethology Science 6*: 19-31

Grandin T 1996 Factors that impede animal movement at slaughter plants. *Journal of the American Veterinary Medical Association 209*: 757-759

Grandin T 1997 The design and construction of facilities for handling cattle. *Livestock Production Science 49*: 103-119

Grandin T 1999 Principles for low-stress cattle handling. *Proceedings of the Range Beef Cow Symposium XVI* pp 10. 14-16 December 1999, Greeley, Colorado, USA

Grandin T 2006 Progress and challenges in animal handling and slaughter in the US. *Applied Animal Behaviour Science 100*: 129-139

Grandin T 2007 Animal welfare and meat production. In: Gregory NG (ed) *Animal Welfare and Meat Production* pp 236. CAB International: Wallingford, UK

Gray R and Regan D 2007 Glare susceptibility test results correlate with temporal safety margin when executing turns across approaching vehicles in simulated low-sun conditions. *Ophthalmic and Physiological Optics 27*: 440-450

Gregory NG and Bell JC 1987 Duration of wing flapping in chickens shackled before slaughter. *Veterinary Record 121*: 567-569

Hopkinson RG, Petherbridge P and Longmore J 1966 *Daylighting.* William Heinemann Ltd: London, UK

Kim W, Han H and Kim JT 2009 The position index of a glare source at the borderline between comfort and discomfort (BCD) in the whole visual field. *Building and Environment 44*: 1017-1023

Lomas CA, Piggins D and Phillips CJC 1998 Visual awareness. *Applied Animal Behaviour Science 57*: 247-257

Phillips CJC and Arab TM 1998 The preference of individually-penned cattle to conduct certain behaviours in the light or the dark. *Applied Animal Behaviour Sciences 58*: 183-187

Phillips CJC and Lomas CA 2001 The perception of color by cattle and its influence on behavior. *Journal of Dairy Science 84*: 807-813

Phillips CJC and Weiguo L 1991 Brightness discrimination abilities of calves relative to those of humans. *Applied Animal Behaviour Science 31*: 25-33

Phillips CJC, Morris ID, Lomas CA and Lockwood SJ 2000 The locomotion of dairy cows in passageways with different light intensities. *Animal Welfare 9*: 421-431

https://doi.org/10.1017/S0962728600002748 Published online by Cambridge University Press