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Vigilance as a measure of fear in dairy cattle

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Abstract

Wild animals increase vigilance at the expense of feeding time in response to predation risk or threats from conspecifics. Increased vigilance may therefore indicate increased fear. We tested dairy cattle to determine whether time spent vigilant changed in response to the novelty of their location, the presence of a dog or the presence of an aversive, gentle or unfamiliar handler. We conducted 12 3 min trials per cow on 40 cows tested individually in a large outdoor enclosure containing an attractive food source. The feeders restricted the animal's view so that it could not feed and scan simultaneously, so vigilance time was defined as any time the animal's head was raised. During the initial trials, the degree of vigilance was high, but the amount of vigilance decreased significantly with number of trials. Time vigilant was significantly higher in the presence of a dog than in the presence of a human or when neither was present. In a second experiment, 20 cows, that had been trained to recognise an aversive and a gentle person for 3 weeks prior to testing, were tested in an indoor pen containing an attractive food source with the aversive, gentle, or an unfamiliar person nearby. The presence of the aversive person significantly increased vigilance time compared to the unfamiliar and gentle people. However, vigilance time did not decrease with repeated exposure to the enclosure, perhaps because the testing barn was already familiar. These results suggest that cows alter their vigilance according to their degree of fearfulness toward people and toward different environments, and that measures of vigilance may provide information on the degree of fearfulness of the animals.

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1. Introduction

Fear is an emotional state induced by the perception of danger (Boissy, 1995) that has important effects on the welfare and productivity of farm animals, especially when animals become frightened of the people that handle them (Hemsworth and Coleman, 1998). The effect of animals' fear of people on productivity is apparent from research on dairy cattle: farms where cows are most frightened of people have lower levels of milk production, and between 19 and 50% of the variance in milk production among farms can be explained by degree of fear the cattle show towards people (Hemsworth et al., 1995; Breuer et al., 2000). Seabrook (1984) reported a yearly difference of 13% in milk production between aversively and gently handled cows, while Rushen et al. (1999) demonstrated that cows will actively withhold milk in the presence of an aversive handler. Studies comparing other domestic species have reported similar results (reviewed in Hemsworth and Coleman, 1998).

A biologically relevant measure of fear is required to develop management practices that reduce animals' fear of people and improve the nature of human–animal relationships (Rushen, 2000). An animal's fear of people is often measured as the distance that the animal keeps from a handler (Boissy and Boissou, 1988; Hemsworth et al., 1994; Munksgaard et al., 1997; Breuer et al., 2000), the time to approach a handler (Hemsworth et al., 1981; de Passillé et al., 1996; Breuer et al., 2000), or the ease with which the animal can be handled (Seabrook, 1984; Albright, 1993; Boivin et al., 1994). While these measures are interpreted as measuring fear, they may be influenced by other factors, such as curiosity, positive associations with the person due to food provisioning, and general activity level. An animal's aversion to a person is best measured in terms of the "cost" the animal is willing to pay to avoid that person (Rushen, 1986). Maintaining distance from a person is not costly to perform, so an animal may avoid a person even if it is not particularly fearful. If the behaviours chosen to measure fear were costly, their performance should be more closely related to the degree of the animals' fear.

We propose that vigilance in the presence of an attractive feeding opportunity can be used as an indicator of fear (Rushen, 2000). Vigilance is behaviour that increases the probability that an animal will detect a given stimulus at a given time (Dimond and Lazarus, 1974). While vigilance may serve to detect a variety of relevant stimuli, its primary function appears to be the detection and avoidance of predators (Quenette, 1990; Hunter and Skinner, 1998; Boland, 2003). Many studies on wild animals show that vigilance is influenced by factors that affect predation risk, such as predator presence, group size, distance to cover, view obstruction, and position within a group (reviewed in Elgar, 1989).

When feeding inhibits an animal's ability to scan its environment and vice versa, a conflict will exist between the two behaviours (Lima and Dill, 1990). The resolution of the resulting trade-off should depend on the energetic requirements of the animal (Arenz and Leger, 2000) and the risk of predation it faces (see Lima and Dill, 1990, for review).

This paper examines the use of vigilance as a potential indicator of fear in dairy cattle. The first objective of this study was to develop a method of measuring vigilance and to see whether it changed in response to a novel environment and to a potential predatory threat. Unfamiliar environments may favour higher vigilance because potential sources and locations of danger are not known, and animals would require more time to find a refuge in case of a threat. Dairy cattle have been protected by humans and have been selected for tameness for

many generations. Reduced predation may lead to reduced behavioural sensitivity to predators over evolutionary time (Price, 1999; Berger et al., 2001). However, large carnivores remain important predators of free-range domestic cattle, accounting for 147,000 deaths in the USA in 2000 (USDA, 2001), so it is possible that behavioural responses to predators would persist despite domestication. Therefore, we used a dog as a potential predator-like stimulus to determine whether it elicited an increase in vigilance using our measure. In domestic sheep, a live domestic dog elicits more realistic anti-predator behaviour than a taxidermic model (Vandenheede et al., 1998). We then examined differences in vigilance in response to people who had previously handled the cattle either aversively or gently. We argue that increased vigilance in response to potentially threatening stimuli and situations provides evidence that measures of vigilance can provide a simple and valuable measure of fear in cattle.

2. Methods

We used Holstein cows and heifers, housed and cared for according to the recommended codes of practice (Agriculture Canada, 1990). Experimental procedures and treatments administered to the animals were approved by the Institutional Animal Care Committee of the Lennoxville Research Centre in compliance with the requirements of the Canadian Council on Animal Care.

2.1. Experiment 1

This experiment involved developing a method for measuring vigilance and testing whether vigilance in cows changed in response to novelty of location or to stimuli associated with different levels of threat (an unfamiliar person or a dog).

The tests were carried out in an enclosure in which the animals had never before been held. The enclosure was adjacent to the barn and measured approximately 150 m². It was surrounded by wire fencing 1.5 m high and was entered via a door on the side of the barn. A wooden feed box (30 cm × 20 cm × 15 cm high) in one corner was filled with highly palatable calf starter feed (Co-op Moulée Super, 19% protein) before each cow entered the enclosure so that feed was available to the cows throughout their time in the enclosure. The fence adjacent to the feed box was bordered by a dense hedge 1.25 m high, blocking the animals' view when their heads were down or feeding. An observation booth with a small window, covered with mesh to conceal the observer, was placed outside the enclosure on the corner opposite to the feeder. Stimuli were presented next to the observation booth. The position of the feed box relative to the hedge and the observation box forced animals that were eating to both lift and turn their heads to see the stimuli.

We tested 40 non-lactating Holstein dairy cows over 5 weeks (8 cows per week). These animals were housed outdoors and brought to the barn daily for the experiment. They were fed a total mixed ration at 07:00, tested between 09:00 and 12:00 and had access to grazing pastures from 12:00 to 07:00. Each cow was observed individually for three sessions per day on 4 days in the same week for a total of 12 sessions. All the eight cows were tested in a given session before the next session began, so the interval between sessions for each individual was about 1 h. Observations were recorded on a hand-held computer using The Observer 2.1

(Noldus) software in 3 min sessions that began as soon as the animal entered the enclosure and the door to the barn was closed. As in other studies of vigilance in ungulates and other mammals (e.g., Underwood, 1982; Hunter and Skinner, 1998; Childress and Lung, 2003), the cows were considered to be more vigilant when their heads were raised than when their heads were lowered. Because of cows' wide field of vision, it is difficult to determine when a cow is able to see any given object when its head is raised. However, the layout of the enclosure and the relative position of the feed box and the stimuli allowed us to determine when the animal was being "non-vigilant". When an animal was feeding, it would have been unable to see the potential threat and less able to see other events in its environment. Therefore, vigilance was scored whenever the animal did not have its head in the feeder or its muzzle within 15 cm of the ground. In these positions, the animal would be less likely to be able to see and respond to the stimulus than when its head was raised.

Nine of the 12 sessions per cow were considered habituation sessions in that no stimulus was presented. Sessions 6, 9, and 12, that is, the third session on the second, third and fourth days of testing, were experimental sessions. During these three experimental sessions, either a dog, a person, or neither (control) was present outside the fence next to the observation booth when each animal entered the enclosure. The order was balanced across cows. The dog was a large (38 kg) Collie–Bernese mixed breed. It showed no interest in the cows and simply sat, staring at the nearby fields during the test sessions. We used one of two people, a male and a female, both approximately 1.7 m tall, unfamiliar to the cows and dressed in casual clothing. Half of the cows were tested with one person and the other half with the other person. The people remained motionless and looked at the cow in the enclosure.

2.2. Experiment 2

The purpose of this experiment was to see if cows would be more vigilant in the presence of a person who had handled them aversively compared to when they were in the presence either of a person who handled them gently or an unfamiliar person.

This vigilance test was performed on 24 lactating Holstein cows that had been subjects in a previous experiment designed to determine whether cows could discriminate between individual humans and to evaluate their behaviour in the presence of people who had treated them differently (Welp, 2001). One person had handled the cows gently, while the other handled the cows aversively. The treatments were similar to those described in Munksgaard et al. (1997) and Rushen et al. (1999), and were chosen to mimic the range of treatments that dairy cattle receive on commercial farms. Aversive treatments involved mainly hitting with the open hand on the head or flanks of the cow and shouting, while gentle treatments involved patting, stroking and feeding the cow and talking in a gentle voice. Cows had received these treatments over a period of 3 weeks that ended within 1 month of the beginning of the present study and did respond to the two handlers differently, avoiding the aversive handler and approaching the gentle handler in a standardized test (Munksgaard et al., 1997) in both familiar and unfamiliar locations (Welp, 2001).

Two pens (4 m × 4.1 m and 4 m × 3.1 m), constructed using 1.5 m metal fencing, were used for the vigilance tests. They were situated in two barns, within view of the cows in their home stalls. A feeder was placed in one corner, and the floors of both enclosures were covered with wood shavings.

The feeders were 75 cm × 75 cm and were 130 cm high with one side partially open, and filled with highly palatable calf starter before each test. The sides of the feeder substantially reduced the animal's field of vision when it put its head inside.

Tests were conducted between 10:00 and 14:00. The cows were tested in three sessions per day for a total of 12 sessions each. Following nine 5 min habituation sessions with no people present, the animals completed three 5 min test sessions, one with the previously gentle handler, one with the previously aversive handler and one with an unfamiliar person who had not previously handled the animal. The order of presentation of the people was balanced across cows. During the 30 s preceding the test, the person walked slowly along one side of the pen until he/she reached a designated location 70 cm from the pen at the corner opposite the feeder. Upon reaching the designated location, the person addressed the cow ("Hello cow, I have arrived"), in order to ensure that the animal was aware of the presence of the person, then stood still watching the cow for 5 min.

The cows' behaviour was recorded during all sessions using three cameras placed to obtain a close-up image of the feeder and two overall views of the enclosure and a Panasonic VHS 6730 video-recorder connected to a multiplexer (multiple imaging system) that sequentially recorded images from all cameras.

Behaviour was measured from the video recordings using The Observer version 3.0 software after the tests were completed. The relative position of the feeder and the person prevented the cow from seeing the person when its head was in the feeder. Therefore, we defined non-vigilant time as the time the cow had its head in the feeder and vigilant time as everything else. During data extraction, the recorder was blind as to the identity of the cows as well as to which person was presented.

3. Statistical analyses

Experiment 1 resulted in multiple measurements of vigilance for all animals, so we analysed the data for the habituation sessions (1–5, 7, 8, 10, 11) with a General Linear Model (GLM) using individual cow and session as factors (equivalent to a repeated measures analysis with session and individual cow as blocked units). To examine the effect of stimulus, we repeated the analysis on the data for the three stimulus sessions and added stimulus as a factor. We used a Scheffé post hoc test for differences between pairs of stimuli.

In experiment 2, we analysed the vigilance time in the three experimental sessions using a GLM that included individual identity of each cow, session, and person as factors. We used a Scheffé post hoc test for differences between people. We also performed a Spearman rank correlation on the individual vigilance times in the presence of the three people. Four cows that were always vigilant during the last habituation session had to be excluded from the analysis because there was no possibility for them to increase vigilance in response to the people.

In both experiments, the data were not normally distributed due primarily to a number of animals being either minimally or maximally vigilant. However, a Levene's test showed that the variances were homogenous so we did not transform the data. All statistical analyses were performed using SAS version 6.0.

4. Results

4.1. Experiment 1

There was a significant effect of both individual cow ($P < 0.001$) and session number ($P < 0.05$) on vigilance over the habituation sessions (Fig. 1). The average percent time vigilant during the nine habituation sessions decreased from 84% in the first session to 43% in the 11th session (Fig. 1).

There was a significant effect of stimulus on vigilance ($P < 0.001$). The mean percent time vigilant was highest for the dog, lower for the human, and lowest in the control session (Fig. 2.). The Scheffé post hoc test showed that the dog elicited greater vigilance than the control ($P < 0.001$) and the person ($P = 0.039$). The difference between the control and the person was not significant ($P = 0.17$).

4.2. Experiment 2

Cow identity ($P < 0.001$) and person identity ($P = 0.013$) had significant effects on vigilance, while session number had a near-significant effect ($P = 0.063$). However, unlike

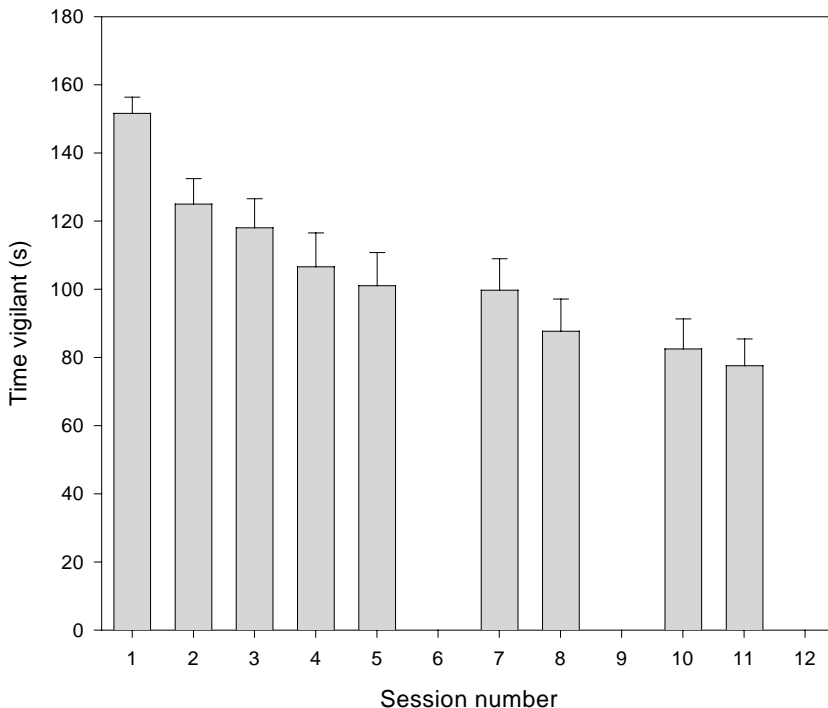


Fig. 1. Mean (+S.E.) time vigilant out of 180 s during habituation sessions from experiment 1 ($n = 40$). Sessions 6, 9 and 12 were used as test sessions.

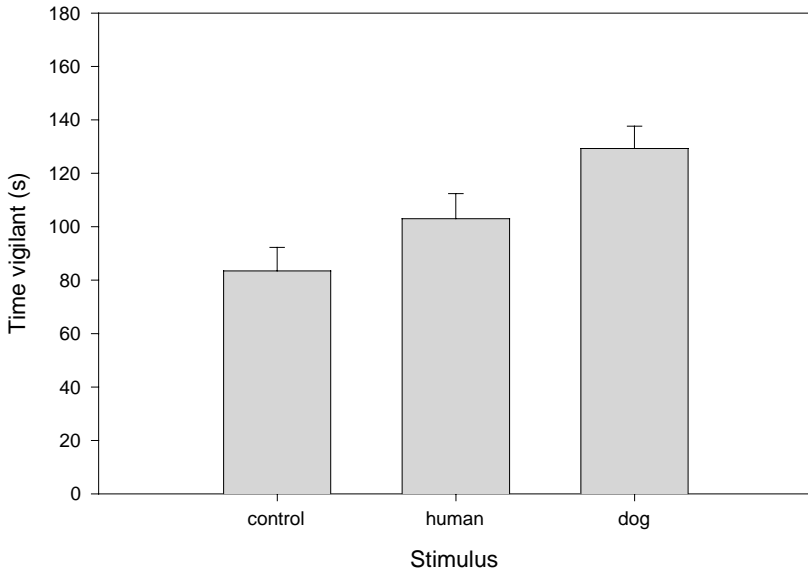


Fig. 2. Mean (+S.E.) time vigilant out of 180 s in the presence of a dog, a person, or neither (control).

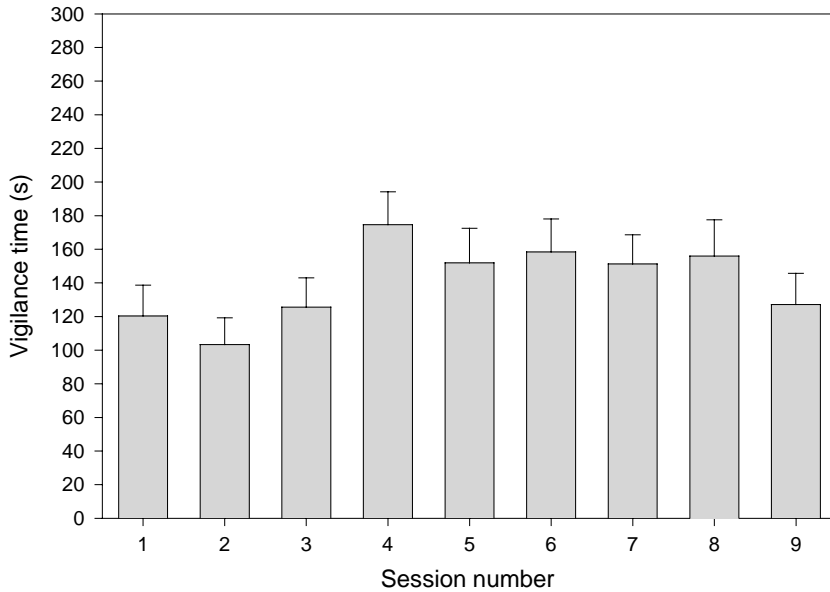


Fig. 3. Mean (+S.E.) time vigilant out of 300 s during habituation sessions in experiment 2 ($n = 20$).

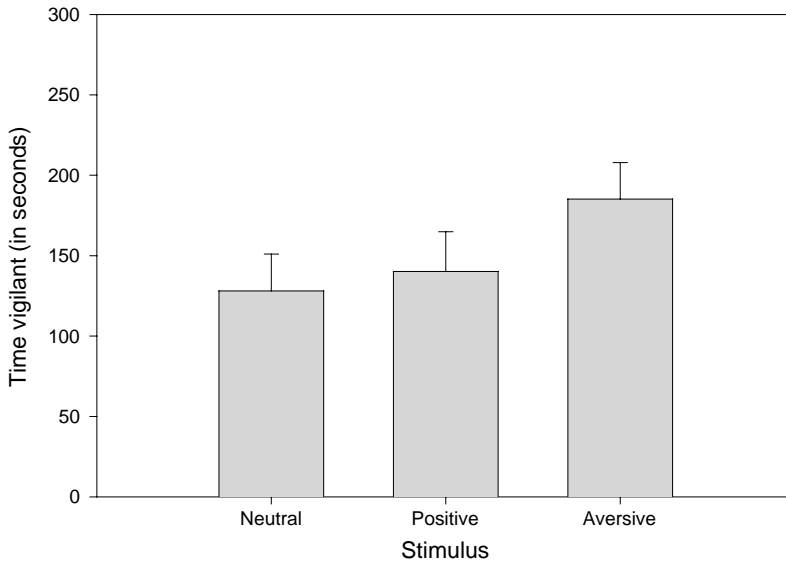


Fig. 4. Mean (+S.E.) time vigilant out of 300 s when the neutral (unfamiliar), positive (gentle), and aversive people were presented in experiment 2 ($n = 20$).

experiment 1, there was no consistent decrease in vigilance with increased experience in the enclosure (Fig. 3). The range of mean vigilance times, from 65.6% (session 2) to 41.8% (session 4), was similar to the range recorded from the fourth to the ninth habituation sessions in experiment 1 (59.2–43.0%).

The mean vigilance times were highest in the presence of the aversive person, lower in the presence of the gentle person, and lowest in the presence of the unfamiliar person (Fig. 4). A Sheffé post hoc test revealed that cows were significantly more vigilant when the aversive person was present compared to the unfamiliar person ($P = 0.02$) and nearly so when compared to the gentle person ($P = 0.069$). There was no significant difference in vigilance time in response to the gentle versus the unfamiliar person ($P = 0.855$).

Among individual cows, the level of vigilance was moderately correlated between responses to the positive and the aversive person ($r = 0.69$, $P < 0.001$), the positive and the neutral person ($r = 0.71$, $P < 0.001$), and the aversive and the neutral person ($r = 0.55$, $P = 0.01$).

5. Discussion

We found that cattle were more vigilant in novel locations, in the presence of a dog, and in the presence of a person who had handled them aversively. We argue that together these results support the idea that measures of vigilance can be used to measure fearfulness in cattle.

The effect of novelty was apparent in experiment 1, where the mean time vigilant decreased with increased exposure to the testing environment (Fig. 1). The test enclosure was new to these animals in the first session but became more familiar with repeated testing over a period of several days. Similarly, Desportes et al. (1991) showed that food-deprived doves (*Streptopelia risoria*) reduced their amount of vigilance and increased their feeding rates as they gained experience with a novel cage over a series of days, and Trouilloud et al. (2004) found that head raising rates in wild chipmunks (*Tamias striatus*) declined over the course of repeated visits to the same food patch. We interpret the decrease in vigilance as habituation to the enclosure during the experiment. This effect of habituation was not apparent in experiment 2. Although there were a number of differences between the two experiments (e.g., size of enclosure, presence of other cows) that may have been responsible for this, we suggest that the lack of apparent habituation in experiment 2 was probably because the animals were more familiar with the location, which was inside the barn and in view of their home stalls. This interpretation is supported by the fact that the mean time vigilant in the habituation sessions in experiment 2 was similar to that measured during the later habituation sessions in experiment 1.

Since dairy cows in novel environments show a variety of behavioural and physiological responses normally associated with fearfulness (Kilgour, 1975; Dantzer et al., 1983; Kondo and Hurnik, 1988; Munksgaard and Simonsen, 1995; de Passillé et al., 1996), we suggest that the changes in vigilance due to habituation provide initial support for the use of vigilance as a tool to measure the fear induced by different locations in dairy cattle. It is possible that the decreased vigilance that occurred as the cows became familiar with the enclosure partly reflected changes in the cows' curiosity rather than fearfulness. However, as we discuss below, the pattern of the cows' responses to the dog and the gentle and aversive handlers makes this interpretation less likely.

Cows were more vigilant when a dog was present. While vigilance has a clear selective advantage as an anti-predator behaviour for wild animals, it has been suggested that the lack of predation over evolutionary time may lead to reduced behavioural sensitivity to predators (Berger et al., 2001; Price, 1999). Previous studies have shown that populations with no predators are less vigilant than similar populations with predators (Bøving and Post, 1997; Berger et al., 2001). In experiment 1, we assumed that the dog should be a threatening stimulus because it resembled a potential predator. The fact that it elicited the highest levels of vigilance suggests that cows found it threatening. Deer show increased vigilance in more dangerous locations and in the presence of predators (Altendorf et al., 2001; Lingle and Wilson, 2001; Childress and Lung, 2003). The higher level of vigilance may have been partly a response to the novelty of the dog. However, the cows were more vigilant in the presence of the dog compared to the presence of a person who was also unfamiliar, suggesting that novelty alone is not a sufficient explanation. Nevertheless, the cows had had more experience with people than with dogs, so we can not rule out an influence of curiosity in this experiment.

The results of experiment 2 allowed us to further test the relative importance of the cows' fear and curiosity. Because we had tested the cows prior to the vigilance test, we knew that the cows recognised both handlers but that they avoided the aversive handler more than the gentle handler, even though both handlers were equally familiar to the cows (Welp, 2001). As predicted, cows were more vigilant with the aversive person than with either

the gentle person or the unfamiliar person. There was no difference in vigilance between the gentle person and the unfamiliar person. This result demonstrates that cows alter their level of vigilance in direct response to the threat posed by a person, rather than by the unfamiliarity of the person. A variety of mammals and birds show patterns of increased vigilance in animals more vulnerable to attack by conspecifics (e.g., Waite, 1987; Roberts, 1988; McDonough and Loughry, 1995; Treves, 2000). Increased vigilance in the presence of an aversive person may reflect a similar response to a threat that is non-predatory.

There was considerable variation among cows in vigilance time. Many studies have reported different levels of vigilance within a group due to position within the group, foraging ability, social status, body condition, age, and sex (reviewed in Elgar, 1989). The cows in our study were observed individually, fed equally, were within a narrow age range (2–8 years), of similar reproductive status, the same sex and of similar body condition. The correlation analysis in experiment 2 showed that differences between individual cows in the time spent vigilant remained stable no matter which person was presented. That is, although they were more vigilant with the aversive than the neutral person, those cows that tended to be more vigilant than average with one person were also more vigilant with the others. This characteristic may make vigilance an interesting measure of temperament in dairy cattle. Temperament is defined as the way animals react to novel or challenging situations (Wilson et al., 1994) and has implications in animal husbandry (Boissy and Boissou, 1995). In order to measure temperament, behaviours that are repeatable (consistent within an individual) (Réale et al., 2000) and are good indicators of how cows react to numerous handling situations are needed (Boissy and Boissou, 1995). Consistent individual differences in vigilance may be correlated with common temperament measures such as shyness and boldness.

As in other studies of vigilance in other animals (e.g., Underwood, 1982; Hunter and Skinner, 1998; Lima and Bednekoff, 1999; Childress and Lung, 2003; Creswell et al., 2003), the cows were considered to be more vigilant when their heads were raised than when their heads were lowered. We did not attempt to use the orientation of the cows' gaze. Because of cows' wide field of vision, it is difficult to determine when a cow is able to see any given object when its head is raised. Hence, we could not with any certainty determine that the cow was paying attention to the stimulus. Furthermore, although vigilant animals may often direct attention toward a particular object, vigilance may also be related to a more general capacity to perceive any relevant stimuli in the environment.

Although we could not determine if the cow was paying attention to the stimulus we presented, the layout of the enclosure and the relative position of the feed box and the stimuli did allow us to determine when the animal was being "non-vigilant". When the cow had its head in the feeder or close to the ground, it would be less likely to be able to see and respond to the stimulus we presented, or other stimuli in its environment than when its head was raised. Studies of other animals that feed from the ground have shown that detection of predators occurs sooner when animals have their heads raised and that the frequency with which animals raise their heads is a good predictor of the speed of response to predators (e.g., Lima and Bednekoff, 1999; Creswell et al., 2003). Thus, we were able to define non-vigilance with more confidence than vigilance. To improve the measurement of vigilance, however, a wider range of behaviours, including head orientation, ear position, etc. may be useful in further studies.

Although vigilance remains in the behavioural repertoire of dairy cows, the lack of predation over evolutionary time may have had other effects. Price (1999) suggested that one of the effects of domestication is increased genetic and phenotypic variability in behaviours that are less important in captivity than in the wild. While vigilance behaviours may be too useful to be lost, reduced selection pressure might have led to greater variability in vigilance behaviours in dairy cows. It would be interesting to compare the variability in vigilance among individuals of beef and dairy breeds with that of feral populations.

The applied objective of this study was to develop a useful measure of fear in dairy cattle in order to measure the level of fear that animals expressed in the presence of their caretakers on commercial farms. We conclude that vigilance in cows can be measured as a trade-off between feeding and vigilant behaviours as defined in our study and that when other factors were controlled, the vigilance level of individual cows was determined by the threat posed by the stimuli presented.

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