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Use of a pneumatic push gate to measure dairy cattle motivation to lie down in a deep-bedded area

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ABSTRACT

Persistence of willingness to work has been used to measure the importance of resources and performance of species-specific behaviors. Our objectives were to develop and validate a "push-door" model to assess cattle motivation to lie down in a deep-bedded area. Motivation for lying was manipulated by forcing dairy cows to stand for 4 h/d in the hours before evening milking (Deprivation, n = 8) or not (No-deprivation, n = 8). Cows in both treatments were individually housed in pens divided into 2 areas: (1) with deep bedding and (2) with feed, water, a brush and wooden grids on the floor to discourage lying down. Cows pushed a one-way pneumatic gate in order to move from the feeding area to the deep-bedded area and could return via an unweighted, one-way gate. Once trained to use the pneumatic gate, the resistance required to open it was increased by 28 kg-f/d until cows no longer used it or the maximum resistance was reached (258 kg-f). We predicted that Deprivation cows would exert more effort to open the pneumatic gate, show a shorter latency to use it after evening milking, and would make fewer unsuccessful attempts compared to cows that were not deprived. We found that Deprivation cows used the pneumatic gate more frequently overall (6.8 ± 0.4 vs. 5.5 ± 0.4 bouts/d, respectively; P = 0.039) and sooner after milking (Deprivation: 29 ± 16 vs. No-deprivation: 95 ± 15 min/d; P = 0.004) compared to those with continuous access. As a result, a similar lying time of 13 h/d was maintained between treatments. There were no other differences, including in the maximum force pushed (Deprivation: 219 ± 14 vs. No-deprivation: 224 ± 11 kg-f; P = 0.992). Five cows pushed the maximum force (40% of average body weight of cows in this experiment), thus no ceiling price was reached for these individuals. This was despite that cows showed signs of physical limitations as the pressure on the pneumatic gate increased: they engaged in more frequent and longer duration of unsuccessful attempts to use it. For example, by the end, the cows tried, on average, to open the gate 19 times on the day they quit or reached the maximum (range 2–39 attempts for individual animals). Finally, once given free-access to the deep-bedded area, cows showed a rebound response, increasing their lying to 17.9 h/d, and reducing time spent feeding by 32% relative to previous days, illustrating their motivation to use this area. The results from this experiment indicate that increasing the resistance required to access a deep-bedded area until cows no longer used it or the maximum resistance was reached may underestimate the considerable motivation dairy cows have to access and lie down in a deep-bedded area.

1. Introduction

Motivation to lie down in dairy cattle has been quantified using at least three approaches: (1) operant methods that involve cows pressing a panel as "work", (2) time constraints and (3) effects of deprivation. In the operant approach, cattle are housed in tie stalls that control when they lie down (e.g. Jensen et al., 2004a) and where the animals are then trained to press a lever to gain access to this opportunity. Research using this approach has demonstrated that heifers will work to gain access to 12–13 h/d of lying (Jensen et al., 2005). In the second approach, cattle are given a limited amount of time and then asked to prioritize how they spend it. For example, in one study, cattle were forced to stand for 3 h without food or a lying area, and then given simultaneous access to both resources. Cows predominately chose to lie down, rather than to feed (Metz, 1985), thus providing insight into their motivation to rest relative to eating. Similarly, Munksgaard and colleagues have given cows a limited amount of time to lie, eat and engage in social behavior over 24 h. They found that cows prioritized time spent lying over eating or social contact in both early and late lactation (Munksgaard et al., 2005). Finally, motivation to lie down can

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also be quantified by recording of consequences in terms of both behavioral and physiological responses to thwarting of rest. For example, numerous studies have found that cattle quickly lie down after periods of forced standing (e.g. Krebs et al., 2011; Norring and Valros, 2016).

These approaches yield valuable information about motivation, but methodological considerations limited their usefulness to answer specific questions. For example, it would be valuable to know how flooring in freestall barns or how time spent eating influences cattle motivation to lie down. The time constraint or deprivation approaches could be used to evaluate the effects of flooring, however, our ability to ask questions about treatments that also influence time budgets, as in the case of eating or grazing, is inherently limited. The panel-pressing approach could also potentially be used to answer both questions (effects of flooring, time spent eating), but this method requires control over the reward duration (e.g. the length of the lying bout "earned"; periods of approximately 50 min in Jensen et al., 2005). Control over reward length is possible when animals have more freedom of movement, as cows have in freestalls or at pasture. Examples of this are calves working for access to space (Jensen et al., 2004b), horses working for access to social contact (Søndergaard et al., 2011) and loose housed pigs working for access to rooting materials (Pedersen et al., 2005). However, testing schedules are labor-intensive. Also, the operant approach applied to motivation for rest has, historically, had animals work only for a proportion of the rest they need. For example, cattle could lie down, on their own, for between 6 and 9 h, but were then asked to work for any additional access to rest (Jensen et al., 2004a,b, 2005). As with the time-budget approach, this restriction makes it challenging to use the operant approach to ask questions explicitly related to shifts in how cattle spend their time. Thus, alternative methodology is needed.

Asking animals to perform physical work, in the form of pushing, has also been widely used to evaluate motivation for resources and performance of species-specific behaviors (Mason et al., 1998). For example, mink will push more than their body weight to gain access to and swim in a water bath (Mason et al., 2001) and hens will push more weight to access and eat after food deprivation than before (Olsson et al., 2002). This research all utilizes an 'entrance fee' approach: once the animal pays to access a resource, they can use it for as long as they like. As a result, animals can compensate e.g. at higher prices, pay less often but maintain the same use (e.g. Cooper and Mason, 2001). Because animals can vary the ratio of price to reward in this type of experiment, calculations of elasticity are not straightforward and, as a result, the metric of interest is the maximum price, or what the animals are willing to push. Indeed, others have argued that maximum price may only be used to compare motivation for the same behavior (in this case, rest or lying) under different environmental conditions (Jensen and Pedersen, 2008).

Our objective was to develop and validate a "push door" to quantify motivation to access a deep-bedded lying area suitable for lying down. We used a model of forced standing to create treatments where motivation to lie down would vary: cattle either had 24 or 20 h of access to a deep-bedded area through a pneumatic gate each day. Cows in the 20 h treatment stood for 4 continuous hours each day. This type of deprivation has been demonstrated to increase motivation to lying down (Cooper et al., 2007; Norring and Valros, 2016). We predicted that dairy cattle forced to stand for 4 h/d would show more motivation to access a deep-bedded area by showing quicker latency to lie down after the forced standing ended, pushing more, and performing more attempts to use the pneumatic gate.

2. Materials and methods

The experiment was conducted at Aarhus University's Cattle Research facility in Foulum, Denmark in spring 2014 and according to a protocol approved by the Danish Animal Experiments Inspectorate, Ministry of Justice, Copenhagen, Denmark (permit number 2013-15-2934-00933).

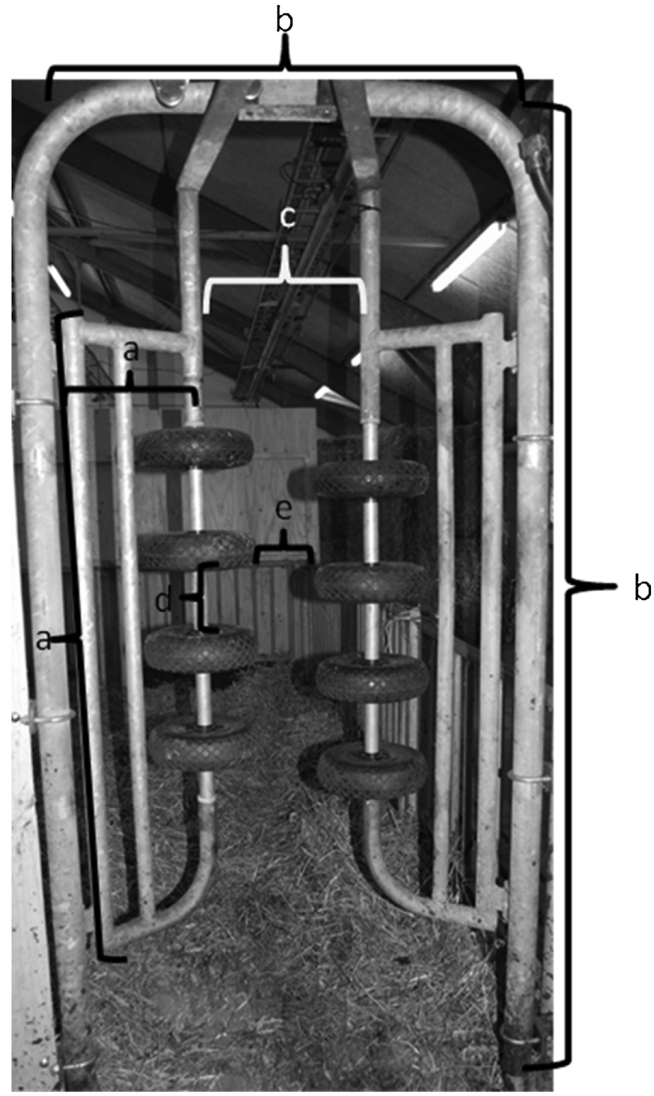

Fig. 1. Pneumatic gate used to access the deep-bedded lying area from the feeding area. It consisted of two panels (each 159 × 30 cm; a) made from metal pipe (diameter; 33–42 mm) attached to a metal frame (209 × 88 cm length, 60 mm diameter pipe; b). The pneumatic gate was mounted on the frame at a 21° angle, with a 32-cm gap (c) between the two panels. Four (260 × 85 cm) rubber tires (Deli tire 300-4, Grene Danmark A/S, Skjern, Denmark; filled to 1 bar pressure) were fixed to the center pipe on each panel. The tires were 15 cm apart (d) and staggered; the horizontal distance between any two was 11 cm (e).Two pneumatic cylinders (CP96 SDB50-500, SMC Pneumatics A/S, Horsens, Denmark) were mounted to the top of the frame and controlled the force required to open the gate. An air compressor (model: FX 90, FIAC Air Compressors S.p.A, Bologna, Italy) and pressure gauge (Fritz Schur Teknik, Denmark) were connected to these cylinders, allowing for the pressure holding the gate closed to be adjusted from 0 to 18 bar.

2.1. Animals and housing

Sixteen lactating Holstein-Friesian cows [average parity 1.8 ± 0.3, DIM 198 ± 12 and BW 622 ± 15 kg (mean ± SE)] were tested in 4 replicates of four. Cows were housed individually in 9 m × 6 m pens divided into two 4.5 m × 6 m sections. One section (feeding area) had a rubber floor (Kura Flex, Kraiburg, Tittmoning, Germany) covered with wooden grids (2.5 cm wide and 10 cm high, creating squares of 0.9 m × 0.9 m) to discourage lying (Schütz et al., 2008) and contained two feed buckets, an automatic waterer (23 cm diameter and 11.5 cm depth) and 6.5 cm by 47 cm wall-mounted brush. The flooring in the deep-bedded area was 10 cm straw over 30 cm sand (Kosand brand;