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Sprinkler flow rate affects dairy cattle avoidance of spray to the head, but not overall, in an aversion race

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ABSTRACT

Spraying cattle with water elicits behavioral responses ranging from willing use to avoidance of wetting the head or entire body. This variation may be partly explained by sprinkler flow rate, as higher flow rates result in greater heat abatement and spray impact. An aversion race can be used to evaluate the emotional valence cows associate with treatments, based on the prediction that they will approach negative (vs. positive) stimuli more slowly and require greater pressure from a handler. Our objective was to evaluate how heat load affects the degree to which dairy cattle show reluctance to approach sprinklers with different flow rates in an aversion race. We compared unsprayed treatments (n = 8 with feed, n = 16 without) to 0.4 L/min (n = 14) and 4.5 L/min (n = 17) sprinklers, which differed eight-fold in spray impact (1.1 vs. 8.9 kPa, respectively). Over 10 trials, cows were required to approach treatments in a covered, narrow raceway (average outdoor air temperature, mean ± SD, 31 ± 3.8 °C). We compared time to complete the race (transit time), the pressure handlers applied, and head posture. Overall, handlers applied pressure half as often when feed was offered but there were no other treatment differences in handling pressure or transit time. Thus, we excluded the feed treatment when examining interactions with heat load and sprinkler flow rate. In warmer weather, transit time increased (by 13 s per 10 °C increase). As their respiration rate increased, unsprayed cows moved more slowly (by 7 s per 10 breaths/min increase), whereas sprayed cows did not. Handling pressure was not affected by heat load or spray application, but head posture depended on sprinkler flow rate. When cows approached 4.5 L/min, they lowered their heads nearly five times as often compared to 0.4 L/min or no spray (proportion of trials ± SE, 0.81 ± 0.05, 0.17 ± 0.06, and 0.15 ± 0.05, respectively). This may have been an attempt to reduce exposure of sensitive body parts to higher-impact spray. Indeed, when we applied von Frey monofilaments to the ear and shoulder (n = 56), the ear had a lower response threshold (greater sensitivity) than the shoulder [mean (95% confidence interval), 0.2 (0.1 to 0.4) vs. 1.2 (0.5 to 2.5) g of force, respectively, back transformed from natural log values]. In conclusion, each measure provided different insights about reluctance to approach treatments. Transit time increased in response to heat load rather than aversion. Handling pressure reflected willingness, as it was needed less often when cows were offered a feed reward, but this measure did not differ among sprinkler treatments. Therefore, although cows lowered their heads to avoid exposing sensitive areas to 4.5 L/min spray, they did not show overall aversion to higher-impact spray.

1. Introduction

In dairy cattle, heat load accumulation can result in increased body temperature, decreased milk yield (West, 2003) and fertility (De Rensis and Scaramuzzi, 2003), and in extreme cases, mortality (Stull et al., 2008; Morignat et al., 2014). For heat abatement in hot, dry climates, spraying cows with water is common (e.g., 62% of milking herds ≥500 head in the U.S.; USDA, 2010). In studies that provide spray, this strategy reduces body temperature, respiration rate, and air temperature (**T**) in the vicinity of sprinklers (Kendall et al., 2007; Chen et al., 2013) when compared to shade alone.

In freestalls and drylots that provide spray, sprinklers are typically mounted over the feeding area. In these settings, cattle can choose to stand beneath the spray, and thus their behavior moderates the degree of heat abatement received. Cows' behavioral responses to sprinklers vary across studies, ranging from voluntary

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spray usage (e.g., Chen et al., 2013) to avoidance of wetting the head (e.g., Schütz et al., 2011) or entire body (as reported anecdotally by Marcillac-Embertson et al., 2009). Some of this behavioral variation may be explained by sprinkler flow rate, which determines both heat abatement and spray impact.

Higher flow rates (≥1.3 L/min, when applied for ≥3 min) provide greater heat abatement, both when cows are required to use spray (≥1.3 vs. 0.4 L/min applied intermittently during 1 h; Chen et al., 2015) and when they are given a choice (4.5 vs. 0.4 L/min for 12 min; Chen et al., in review). It is unknown whether cows choose to use spray on the basis of heat abatement efficacy, although it has been shown that they prefer shade that provides better protection from solar radiation (Schütz et al., 2009). If cattle indeed choose spray based on cooling effectiveness, they should prefer higher flow rates. In some studies with higher flow rates, cattle have indeed been found to prefer sprinklers over none (1.3 vs. 0 L/min, and 3.3 vs. 0 L/min, respectively; Parola et al., 2012; Chen et al., 2013), but not in others (2.6 vs. 0 L/min, and 4.5 vs. 0 L/min, respectively; Parola et al., 2012; Chen et al., In review). In addition, in one study, some cows rarely used a 7.3 L/min shower (i.e., <1 h/d; Legrand et al., 2011), and in another, heifers anecdotally avoided 30 L/min sprinklers altogether (Marcillac-Embertson et al., 2009). Nevertheless, although cows preferred sprinklers with a lower flow rate (0.4 L/min) compared to no spray in a 12-min paired comparison, they had no preference between 0.4 and 4.5 L/min sprinklers (Chen et al., in review). Therefore, the role of heat abatement efficacy in determining cattle use of higher or lower flow rates remains unclear.

Cattle may avoid higher flow rates in cooler weather to prevent heat loss. Cows tested when 24-h T averaged 18 °C did not prefer sprinklers compared to shade or ambient conditions (Schütz et al., 2011). Physiological responses also indicate attempts to counteract heat loss: when cows were sprayed in the morning (average T, 24 °C; Araki et al., 1985) or on days with T <23 °C (Kendall et al., 2007), body temperature temporarily increased afterward. When T increased, however, so did the amount of time cows spent using 7.3 and 3.3 L/min spray (Legrand et al., 2011; Chen et al., 2013). Likewise, although cattle did not prefer 2.6 and 4.5 L/min sprinklers compared to shade across all testing conditions, when heat load increased their preference for spray became more marked (Parola et al., 2012; Chen et al., in review).

Cattle might also sometimes avoid higher flow rates because they deliver greater spray impact. The head may be particularly sensitive, and when standing under spray, cattle lower (Kendall et al., 2007; Tucker et al., 2007; Schütz et al., 2011) or keep their heads out of the spray radius (Schütz et al., 2011; Chen et al., 2013). To evaluate whether the head is more sensitive to mechanical stimulation compared to the trunk, von Frey monofilaments can be applied to elicit responses such as ear flicks (previously used in the context of disbudding in calves; Espinoza et al., 2013; Mintline et al., 2013) and skin twitches (e.g., on the withers of ponies; Lansade et al., 2008). Cows exhibited more skin twitches under spray in one study, perhaps in response to droplets (Schütz et al., 2011), but this was not replicated (Chen et al., in review). The effect of spray impact on head-specific avoidance has not been examined.

When cows do not prefer spray, the emotional valence underlying this choice is unknown. The aversion race method has been used to evaluate emotional valence (reviewed by Rushen, 1996), and is based on the principle that animals move less willingly (more slowly, with more pressure from a handler, or both) toward aversive stimuli, which indicates negative emotional valence. Using this method, Pajor et al. (2000) demonstrated that dairy cows perceived being shouted at versus offered feed negatively and positively, respectively, relative to a silent handler without feed. These treatments could provide comparison points to evaluate the emotional valence cows associate with different spray flow rates.

Our objectives were to evaluate sensitivity to mechanical stimulation on the ear and shoulder, and to investigate three questions about spray flow rates: (1) what is the overall emotional valence cows associate with each, (2) how does this variable affect head-specific avoidance, and (3) how does heat load affect cows' willingness to approach each? We predicted the ear would be more sensitive than the shoulder, and higher flow rates would result in more head-specific spray avoidance. We predicted the emotional valence cows would associate with higher flow rates would be less positive than lower ones overall. Finally, we predicted cows would approach spray more willingly when heat load was higher, possibly changing the emotional valence associated with higher flow rates.

2. Materials and methods

2.1. Animals and housing

The study was conducted during summer (June–September 2013) at the University of California-Davis (UC Davis) dairy facility, with all procedures approved by the Institutional Animal Care and Use Committee. Fifty-eight lactating Holstein-Friesian dairy cows (40 pregnant) were selected based on average daily milk yield ≥34 kg, as metabolic heat production increases with milk yield. On average, the cows had daily milk yield (mean ± SD) of 40 ± 4.9 kg, parity of 2.0 ± 1.1, days in milk of 184 ± 73, and body weight of 701 ± 83 kg.

Cows were tested for eight days in nine cohorts (of five to seven cows), each housed in a group of 24 total (including those not being tested). The concrete-floored home pen included two water troughs (automatically refilled to 384 and 716 L, respectively) and 24 shaded, sand-bedded freestalls with two overhead fans (36-DMCH; Future Products Corp., Mosinee, WI, USA). Cows were fed thrice daily during milking (05:00 and 17:00 h) and at 11:00 h with a total mixed ration (**TMR**) formulated to National Research Council (1989) requirements using the PC Dairy system (Bath and Strasser, 1990). The unshaded feed bunk was fitted with 13 soaker nozzles (TF-VP7.5 Turbo FloodJet wide angle flat spray tip, 4.9 L/min; Spraying Systems Co., Wheaton, IL, USA) that delivered 1.5 min of continuous spray, followed by 13 or 5 min off (at T ≥22.2 or 29.4 °C, respectively).

2.2. Procedures in the chute

On d 1 and 8 cows were moved to a chute for sensitivity testing and body temperature logger insertion and removal.

2.2.1. von Frey monofilament testing

Two locations on the right side of the body were selected to represent the head and trunk: the back of the ear and the shoulder (Fig. 1), respectively. Behaviors used to assess responses to mechanical stimulation were an ear flick or a skin twitch on the shoulder. In order to ensure that cows responded to the testing stimuli rather than insects, debris was brushed from the hair coat on both sides of the body and a light coating of insect repellent (Prozap VIP; Neogen Corp., Lexington, KY, USA) was applied around (but not directly on) the testing sites with a washcloth. Sensitivity was assessed using a set of 20 von Frey monofilaments (0.008, 0.02, 0.04, 0.07, 0.16, 0.4, 0.6, 1, 1.4, 2, 4, 6, 8, 10, 15, 26, 60, 100, 180, and 300 g of force; Touch-Test Sensory Evaluators; North Coast Medical Inc., Gilroy, CA, USA), each mounted on a plastic handle. To test each body part, the tip of the 0.008 g monofilament was pressed against the hair coat; once the monofilament bent, it was held in place for 1 s. If a response was observed within 2 s after the monofilament was removed, the threshold was recorded; if not, the next level of force in the sequence was applied. The total time we allowed for a response (3 s) was based on the 3–4 s used to test the hind