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Plasticity and consistency of lying and ruminating behaviours of heifers exposed to different cubicle availability: A glance at individuality

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ABSTRACT

Behavioural responses are a balance between plasticity (changes in behavioural patterns in relation to the environment) and consistency (similar behavioural responses in different situations). In addition, behavioural consistency indicates the presence of individuality, that is, a degree of internal consistency in the way individuals respond to situations. The estimation of the strength of plasticity and consistency in behaviour is a way to explore how coping mechanisms work and the degree to which environmental changes and individuality influence behavioural responses. Therefore, this study evaluated the balance between plasticity and consistency in the rumination and lying patterns of heifers exposed to three cubicle availabilities by comparing the effect size estimates of a repeated measures ANOVA (plasticity) and Kendall's coefficient of concordance (consistency). Heifers lay and ruminated less time on average as cubicle availability decreased (Total lying: $F = 15.38_{2,28}$; $P < 0.0001$ and Total rumination: $F = 167.76_{2,28}$; $P < 0.0001$). Rumination had a stronger effect size estimate of plasticity (Total rumination: 0.88 > 0.38), probably as a result of the importance of this activity for cows' energy acquisition and the low energy cost of this activity. Lying behaviours tended more towards consistency (Total lying: 0.81 > 0.59), most likely to avoid the energy costs of plasticity at individual level. Individuals are consistent in their lying behaviour, which can cause health risks if, despite changes in the environment, heifers lie for too long or not long enough. Further research is needed to address the relationship of individuality and expression of basic behaviours, such as lying and rumination, and the role of individuality in disease prevention.

1. Introduction

Behavioural plasticity is the capacity to adjust behaviours in response to fluctuating environmental conditions. In contrast, behavioural consistency is the execution of similar behaviours under different situations (Sih et al., 2004; Stamps and Groothuis, 2010). Although plasticity is generally considered advantageous, it can also be non-beneficial. Responding adaptively to some environmental stimuli improves accuracy on the proximate expectations, but also increases the uncertainty about the rest of the environment, thus decreasing the ability to cope (Dall and Cuthill, 1997; Dall et al., 2004). In addition, evaluating the environment increases energetic demands, risk exposure and decreases fitness (Komers, 1997).

When the costs associated with plasticity are too high, behavioural consistency becomes advantageous, as it generates similar behaviours across different situations or "approximately appropriate responses" that respond to environmental demands without increasing energy expenditure or risk exposure (Dall et al., 2004). Because individuals tend to respond in consistent modes to challenging situations (Mendl et al., 1992; Mason and Mendl, 1993), behavioural consistency also indicates the presence of individuality (Dall et al., 2004; Briffa et al., 2008). Since individuality varies in intensity along several axes (such as shyness to boldness or aggressiveness (Réale et al., 2007), high consistency and the presence of individuality will also facilitate consistency on behavioural intensity across situations. For instance, consistently submissive individuals might do well in situations where low aggression is favoured, but poorly in competitive situations (Sih et al., 2004).

Behavioural responses are a balance between plasticity and consistency. Such balance is determined by variables such as the level of investment that sensory systems require (Dall et al., 2004; Briffa et al., 2008). Therefore, for any given behaviour, there is a trade-off between plasticity (environment) and consistency (individuality; Briffa et al., 2008). Understanding this trade-off is important to comprehend how coping mechanisms work and the degree of influence that environmental factors have on individuals' behaviour. One way to explore the degree of influence of plasticity and consistency is comparing the effect

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size estimates obtained with two kinds of statistical tests: one calculating the average differences in behaviour between situations (plasticity) and one calculating the stability in ranks of individual responses between situations (consistency) (Briffa et al., 2008).

The statistical test that calculates the effect size of plasticity is the repeated measures ANOVA, which measures average differences in behaviour between situations for individuals that are observed on multiple occasions (Johnson and Sih, 2005). Meanwhile, the statistical test that calculates the effect size of consistency is the Kendall's coefficient of concordance, which measures consistency in differences in behaviour between individuals across multiple situations (Bremner-Harrison et al., 2004). Both tests result in effect size estimates with values between 0–1. If the effect size of the ANOVA (adjusted R^2) is greater than the effect size of the Kendall's coefficient of concordance (W), plasticity would be the dominant trait for that behaviour, whereas consistency would be favoured if the effect size of the Kendall's test is greater (Briffa et al., 2008).

In heifers, maintenance behaviours such as lying and rumination have been well studied because they relate to animal welfare. Rumination is an essential activity for energy intake (Grant and Dann, 2015) and it is affected by external variables such as forage nutritional characteristics (Welch and Smith, 1970) and social structure (Rind and Phillips, 1999). Rumination is also affected by internal variables such as voluntary feed intake which results in changes in rumen fill perceived by the distension of the rumen wall (Campling et al., 1961; Carr and Jacobson, 1967). A decrease in rumination can lead to the development of acidosis (Owens et al., 1998).

Lying behaviour is a priority for cows and is affected by factors such as age, heat, illness, housing system, bedding material, tying system, and stocking density (Krohn and Munksgaard, 1993). However, it has shown to be consistent at individual level (Hopster et al., 2000; Müller and Schrader, 2005). Increases in lying time are related to increased levels of stress hormones (Munksgaard and Løvendahl, 1993; Munksgaard and Simonsen, 1996), lameness (Leonard et al., 1996; Chapinal et al., 2009) and injuries (Rushen et al., 2007). Examining the balance between the plasticity and consistency of these behaviours in heifers in response to an external factor is a step towards understanding how farm animals cope with environmental challenges, as well as an indication of individuality and the existence of differences in the intensity of behavioural features, which could signify a greater health risk for certain individuals. This knowledge is relevant for farm animal welfare and management, as the consistent behaviour of individuals may be related to their ability to cope with husbandry conditions (Manteca and Deag, 1993). Therefore, this study examined the balance between behavioural plasticity and consistency in the proportions of lying and rumination times of heifers exposed to different cubicle availabilities by comparing the effect size estimates of the statistical tests measuring plasticity and consistency. Additionally, we will briefly discuss the implications of individuality in terms of the risk associated with the intensity of behavioural responses.

2. Materials and methods

2.1. Housing and animals

This research was carried out at the Center for Agricultural Education from the Higher Studies Faculty, Cuautitlán-UNAM (19°41′N, 99°11′W). The study protocol was reviewed and approved by the Internal Committee for the Care and Use of Experimental Animals CICUAE FESC (Approval Number C 14_10). Fifteen healthy Holstein dairy cows (631 ± 17 kg of body weight; mean ± SE) with an age range of 4–6 years (5.2 ± 0.1; mean ± SE) were used in this study. Cows were housed in an outdoor pen composed of two rows of 10 cubicles, with a concrete floor and a roof above the rows of cubicles, (Fig. 1). Lamps with white light were mounted on the roof ceiling. Each cubicle had a concrete base with silica sand bedding, which was

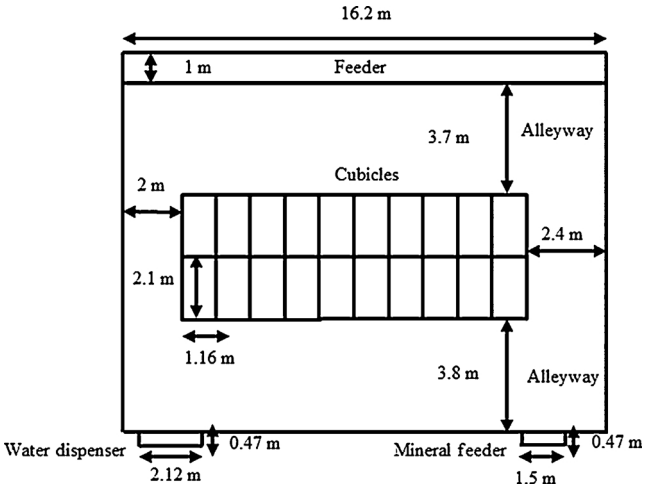

Fig. 1. Schematic view of pen and cubicles (scale 1:200).

cleaned out every third day. Four video cameras (Model KC5942-F, Meriva Security, Guangzhou, China) with infrared light were mounted at each corner of the pen at 4 m height to record overnight. Heifers had *ad libitum* access to salt blocks, feed and water. The ration was composed of a base of corn silage, alfalfa *ad libitum*, and oat straw. Concentrate (Dairy roll with 17% crude protein; CP) was provided 3× per day, once with the morning ration, and during milking (06:30 and 15:30 h).

2.2. Behavioural observations and measurements

A repeated measure design was used to study the effect of cubicle availability on individual behaviours. Cubicle availability during treatments was controlled by blocking access to lesser used cubicles using a rope tied horizontally at the entrance of the cubicles at the height of 1 m. The lesser used cubicles were determined by pilot observations carried out during a habituation period at times where cows were expected to lie (15 days, 2 observers, 2 h per day).

During the experimental phase, three treatments were established: A20 = 20 cubicles available, A15 = 15 cubicles and A8 = 8 cubicles available. Observations were carried out in three consecutive periods each consisting of 12 days. During each period, treatments were imposed for 4 days each in a random consecutive order to all heifers.

Cows were observed daily for 6-h periods. On day one, observations started at 08:00 and finished at 14:00; on the second day cows were observed from 14:00 to 20:00; this process continued consecutively completing a 24-h cycle in 4 days of observation per treatment (Harcourt, 1978). This resulted in 72 h of observations per treatment. All observations were carried out by 3 experimenters. Inter and intra-observer agreement was calculated with the Kappa coefficient (Inter-observer agreement: $\kappa = 0.93$; intra-observer agreement: $\kappa = 0.87$).

The behavioural variable observed were: Lying (proportion of lying time in cubicles, in alleyways and in total) and rumination (proportion of rumination time lying in cubicles, alleyways, standing and in total). These behaviours were recorded by direct observation using scan sampling every 10 min (Martin and Bateson, 2007). Once the observations were complete, behavioural variables were expressed as proportions of observations, calculated as number of observations per behaviour/total number of scan samplings. Likewise, each behavioural variable was averaged by treatment across the three periods (i.e. the proportion of total lying time per treatment divided by 3 replicates) to compare the effect of cubicle availability.

2.3. Statistical analyses

All analyses were performed using the program Minitab for