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Emotions in goats: mapping physiological, behavioural and vocal profiles

Elodie F. Briefer [*,1], Federico Tettamanti [3], Alan G. McElligott [*,2]

Queen Mary University of London, Biological and Experimental Psychology Group, School of Biological and Chemical Sciences, London, U.K.

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Emotions are important because they enable the selection of appropriate behavioural decisions in response to external or internal events. Techniques for understanding and assessing animal emotions, and particularly positive ones, are lacking. Emotions can be characterized by two dimensions: their arousal (bodily excitation) and their valence (negative or positive). Both dimensions can affect emotions in different ways. It is thus crucial to assess their effects on biological parameters simultaneously, so that accurate indicators of arousal and valence can be identified. To find convenient and noninvasive tools to assess emotions in goats, *Capra hircus*, we measured physiological, behavioural and vocal responses of goats in four situations: (1) control (no external stimulus, neutral); (2) anticipation of a food reward (positive); (3) food-related frustration (negative); (4) isolation away from conspecifics (negative). These situations were characterized by different levels of arousal, assessed a posteriori by heart rates measured during the tests. We found several clear, reliable indicators of arousal and valence. During situations of higher arousal, goats had lower heart rate variability and higher respiration rates. They displayed more head movements, moved more, had their ears pointed forwards more often and on the side (horizontal) less often and produced more calls. They also produced calls with higher fundamental frequencies and higher energy distribution. In positive situations, goats had their ears oriented backwards less often and spent more time with their tails up than in negative situations. Furthermore, they produced calls in which the fundamental frequencies were less variable. Our methods for assessing the effects of emotional arousal and valence on biological parameters could lead to more effective monitoring and understanding of animal emotions, as well as to a better understanding of the evolution of emotions through cross-species comparisons.
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Although the existence of animal emotions has been suggested since Darwin (1872), techniques for understanding and assessing these affective states, and particularly positive ones, are still lacking. The discovery of clear emotional indicators is crucial for many disciplines, including animal behaviour, neuroscience, psychopharmacology and animal welfare (Mendl, Burman, & Paul, 2010). Emotions are composed of four components: neurophysiological, behavioural, cognitive and subjective (Keltner & Lerner, 2010).

While there is evidence for a subjective, conscious component of emotions only in humans, the other components can potentially be used as indicators in nonhuman animals (Mendl et al., 2010).

Unlike the 'discrete emotion approach', which suggests the existence of a small number of fundamental emotions, the 'dimensional approach' proposes to characterize emotions according to their two main dimensions: arousal (bodily activation or excitation; e.g. calm versus excited) and valence (negative or positive; e.g. sad versus happy; Russell, 1980). This approach is very promising for the study of animal emotions (Mendl et al., 2010). Its recent use has allowed substantial progress to be made in identifying behavioural (e.g. pigs, *Sus scrofa*, Imfeld-Mueller, Van Wezemael, Stauffacher, Gygax, & Hillmann, 2011; review, Murphy, Nordquist, & van der Staay, 2014; sheep, *Ovis aries*, Reefmann, Bütikofer Kaszàs, Wechsler, & Gygax, 2009a), physiological (e.g. hens, *Gallus domesticus*, Davies, Radford, & Nicol, 2014; sheep, Reefmann, Bütikofer Kaszàs, Wechsler, & Gygax, 2009b) and cognitive indicators of emotional arousal and valence (goats, *Capra hircus*, Briefer &

* Correspondence and present addresses: E. F. Briefer, Institute of Agricultural Sciences, ETH Zürich, Universitätstrasse 2, 8092 Zürich, Switzerland and A. G. McElligott, Biological and Experimental Psychology, School of Biological and Chemical Sciences, Queen Mary University of London, Mile End Road, London E1 4NS, U.K.
[1] E-mail address: elodie.briefer@usys.ethz.ch (E. F. Briefer).
[2] E-mail address: a.g.mcelligott@qmul.ac.uk (A. G. McElligott).
[3] Present address: Department of Science for Nature and Environmental Resources, University of Sassari, Sassari, Italy.

McElligott, 2013; rats, *Rattus norvegicus*, Burman, Parker, Paul, & Mendl, 2008; review, Mendl, Burman, Parker, & Paul, 2009). In addition, the relationship between an individual's inner state and the vocalizations it produces suggests that vocalizations are promising indicators of emotions (Briefer, 2012; Manteuffel, Puppe, & Schön, 2004).

Indicators of emotional arousal have been extensively studied in negative situations (e.g. stress, fear in farm animals, Forkman, Boissy, Meunier-Salaün, Canali, & Jones, 2007). Conversely, studies of arousal indicators during situations of positive valence are rare. Indicators that could allow us to differentiate between negative and positive situations (i.e. valence indicators) have also been poorly studied. Finding indicators of valence requires comparing animals that are exposed to negative versus positive situations. Yet, changes in parameter values between neutral and negative situations are often easier to detect than between neutral and positive situations, because negative emotions often trigger higher arousal levels than positive ones (Boissy et al., 2007). Another concern regarding research on indicators of emotions is that very few studies have investigated both arousal and valence in a given species (but see for example Gogoleva et al., 2010; Soltis, Blowers, & Savage, 2011). Additionally, the emotional situations that are used often differ in both dimensions simultaneously, or may differ in more than simply the emotions they trigger (e.g. comparing the effect of pain as a negative situation versus food reward as a positive one). This results in confusion about which dimension affects the measured parameters. More precise arousal indicators could assist in identifying and thus minimizing stress during negative situations, while more accurate valence indicators could allow us to distinguish between negative and positive situations. This would then lead to enhanced animal wellbeing by promoting situations that trigger positive emotions (Boissy et al., 2007).

In this study, we investigated indicators of both emotional arousal and valence in domestic goats. Goats are highly social and vocal animals that, in the wild (feral goats), live in complex fission–fusion societies (Stanley & Dunbar, 2013). This species should benefit from behavioural or vocal expression of emotions, as a mean to regulate social interactions within groups (Panksepp, 2009). Goats have good cognitive abilities, such as perspective taking (Kaminski, Call, & Tomasello, 2006) and conspecific gaze following (Kaminski, Riedel, Call, & Tomasello, 2005). They have the ability to use indirect information (i.e. the absence of food; Nawroth, von Borell, & Langbein, 2014b) and human pointing and touching cues (Nawroth, von Borell, & Langbein, 2014a) to find a reward. They also have good visual discrimination learning abilities (e.g. Langbein, Nürnberg, & Manteuffel, 2004) and long-term memory (Briefer, Haque, Baciadonna, & McElligott, 2014; Briefer, Padilla de la Torre, & McElligott, 2012). The most common goat vocalization is the contact call, which is used to maintain contact at relatively close distance (Briefer & McElligott, 2011a). Goats produce two kinds of contact calls: closed-mouth and open-mouth (Ruiz-Miranda, Szymanski, & Ingals, 1993). Contact calls contain information about individuality (Briefer & McElligott, 2011a), age, sex and body size (Briefer & McElligott, 2011b), kinship and even group membership of the producer (Briefer & McElligott, 2012). Playback experiments have shown that these vocalizations allow mothers and kids to recognize each other from at least 1 week postpartum (Briefer & McElligott, 2011a), and that mother goats remember the calls of their kids for up to 1 year after separation (Briefer et al., 2012). Goat behaviour and vocalizations have been shown to be affected by the degree of social isolation (complete or partial), suggesting the existence of indicators of negative arousal (Siebert, Langbein, Schön, Tuchscherer, & Puppe, 2011). In terms of potential indicators of

valence, patterns of behaviour, sympathetic reactions and brain activity in goats have been shown to differ between positive and negative situations (i.e. different valence; Gygax, Reefmann, Wolf, & Langbein, 2013). In this study, we assessed physiological, behavioural and vocal profiles linked to both arousal and valence, by testing which dimension was most responsible for changes in the measured parameters.

We combined new frameworks recently adapted from humans to animals to analyse vocalizations (source–filter theory; Taylor & Reby, 2010) and emotions (Mendl et al., 2010), to find noninvasive indicators of emotions in goats. We placed goats in four situations likely to induce different emotional arousal and valence: control (neutral), anticipation of food reward (positive), food frustration (negative) and social isolation (negative). Physiological stress (nonspecific response of the body to any demand made upon it), and thus heart rate, increase with arousal, whether the situation is positive or negative (Seyle, 1976). For this reason, we assessed the arousal triggered by our experimental emotional situations by comparing the heart rates of goats in response to the tests. In the absence of well-established valence indicators in the literature, we inferred the valence of our situations based on knowledge of the function of emotions and on goat behaviour. We tested the hypothesis that emotional arousal and valence in goats are indicated by particular physiological, behavioural and vocal profiles. For instance, we expected physiological parameters linked to the autonomic nervous system (e.g. heart rate variability and respiration rate) to be affected by arousal, while behavioural and vocal parameters could indicate both dimensions (Briefer, 2012; Imfeld-Mueller et al., 2011; Reefmann, Wechsler, & Gygax, 2009). We defined the parameters that changed according to increased arousal levels as reliable indicators of arousal. Similarly, we defined the parameters that changed consistently from negative to positive valence as reliable indicators of valence.

METHODS

Subjects and Management Conditions

The study was carried out at a goat sanctuary (Buttercups Sanctuary for Goats, http://www.buttercups.org.uk), Kent, U.K. We tested 22 adult goats (11 females and 11 castrated males), which were fully habituated to human presence and could be led around using a lead rope (Baciadonna, McElligott, & Briefer, 2013; Briefer & McElligott, 2013), between May and June 2011. They were aged 3–17 years and of various breeds (Table 1). They had been at the sanctuary for at least 2 years (range 2–11 years). Five of these goats (three females and two males) had been rescued and brought to the sanctuary because of poor welfare conditions (three goats) or because they had been found abandoned (two goats). These five goats had been at the sanctuary for at least 4 years in 2011. The other goats had been housed in good conditions and were brought to the sanctuary because their owners could no longer keep them.

All goats at our study site are released into a large field during the day. At night, they are kept indoors in individual or shared pens (two or three goats, average size = 3.5 m^2) with straw bedding, within a larger stable complex. Routine care of the animals is provided by sanctuary employees and volunteers. Goats have ad libitum access to hay, grass (during the day) and water, and are also fed with a commercial concentrate in quantities according to their state and age. Every stable is cleaned on a daily basis. All goats are inspected each day by the sanctuary employees and volunteers, and are checked regularly by a vet and given medication when appropriate.