Applied Animal Behaviour Science 163 (2015) 58–68

Contents lists available at ScienceDirect

Applied Animal Behaviour Science

journal homepage: www.elsevier.com/locate/applanim

Acoustic analysis of cattle (*Bos taurus*) mother–offspring contact calls from a source–filter theory perspective

Mónica Padilla de la Torre[a,*], Elodie F. Briefer[b,1], Tom Reader[a], Alan G. McElligott[b,**]

[a] School of Life Sciences, University of Nottingham, University Park, Nottingham NG7 2RD, UK

[b] Biological and Experimental Psychology, School of Biological and Chemical Sciences, Queen Mary University of London, Mile End Road, London E1 4NS, UK

ARTICLE INFO

Article history:
Accepted 27 November 2014
Available online 8 December 2014

Keywords:
Animal welfare
Calf
Cow
Individuality
Livestock
Vocal communication

ABSTRACT

Cattle vocalisations have been proposed as potential indicators of animal welfare. However, very few studies have investigated the acoustic structure and information encoded in these vocalisations using advanced analysis techniques. Vocalisations play key roles in a wide range of communication contexts; e.g. for individual recognition and to help coordinate social behaviours. Two factors have greatly assisted our progress in developing an understanding of animal vocal communication. Firstly, more rigorous call analysis methods allow us to describe the variation in the vocal parameters in unprecedented detail. Secondly, the adoption of the "source–filter theory" of call production links the acoustic structure of vocalisations to the morphology and physiology of calling animals. Using these approaches, it is possible to quantify the potential for each acoustic component to carry information. In this study, we examined naturally occurring contact calls produced by crossbred beef cows and their calves under free-ranging conditions. Our main aims were to identify vocal parameters, which can be used to characterise cow and calf contact calls, and to describe variation in these parameters under relatively undisturbed conditions. Additionally, we aimed to provide information for future studies on potential acoustic indicators of animal welfare in cattle. We identified two different types of cow contact calls associated with different behavioural contexts, and with differing acoustic structures. Low frequency calls (LFCs) were produced by cows when they were in close proximity to their calves, in the first three or four weeks postpartum, and they were made with the mouth closed or only partially open (fundamental frequency (F0) = 81.17 ± 0.98 Hz). By contrast, high frequency calls (HFCs) were produced by cows when they were separated from their calves (e.g. not in visual contact) and preceded nursing (F0 = 152.8 ± 3.10 Hz). Calf calls were produced when separated from their mothers and preceded suckling (F0 = 142.8 ± 1.80 Hz). A detailed analysis of cow LFCs and HFCs, and of calf calls, showed that all three types of calls are individually distinctive. We also show that calf calls encode age, but not sex. Although it has previously been suggested that cattle contact calls are individually distinctive, to our knowledge, our study

* Corresponding author. Present address: Institute of Agricultural Sciences, ETH Zürich, Universitätstrasse 2, 8092 Zürich, Switzerland. Tel.: +41 44 632 05 85; fax: +41 44 632 11 28.

** Corresponding author. Tel.: +44 20 7882 6682; fax: +44 20 8983 0973.
E-mail addresses: mopat76@gmail.com (M. Padilla de la Torre), a.g.mcelligott@qmul.ac.uk (A.G. McElligott).

1 Present address: Institute of Agricultural Sciences, ETH Zürich, Universitätstrasse 2, 8092 Zürich, Switzerland.

http://dx.doi.org/10.1016/j.applanim.2014.11.017

is the first to use the most rigorous, modern methods to analyse their calls. This study represents an important advance in our knowledge cattle contact vocalisations, which is essential for future work on cattle communication and welfare.

1. Introduction

Vocal communication can convey different types of information and is thus used in many forms of social interactions (Fischer et al., 2002; Taylor et al., 2009; Theis et al., 2007). For example, vocalisations may encode individual identity of the producer (Briefer and McElligott, 2011a). There is also good evidence that vocal cues can inform receivers about physical attributes of the senders (McComb and Reby, 2005). For example, male deer rut vocalisations are used by conspecifics to infer body mass, age and social status (Briefer et al., 2010; Reby and McComb, 2003; Pitcher et al., 2014; Vannoni and McElligott, 2008, 2009), and goat (*Capra hircus*) kid calls reveal information about their sex, age and body weight (Briefer and McElligott, 2011b). These types of information are particularly useful when individuals range widely, because visual or olfactory signals are not always available (Sèbe et al., 2007).

Early research on mammal vocal communication, and particularly applied studies of vocalisations in an animal welfare context, generally focused on easily measured parameters of vocalisations, such as calling rate and behavioural responses of receivers (Grandin, 1998, 2001; Weary and Chua, 2000). These studies often relied on the descriptive analyses and/or classification of calls into types, according to different contexts (Byrne and Soumi, 1999; Marchant et al., 2001; McElligott and Hayden, 1999; Owings and Morton, 1998; Weary and Fraser, 1995). Recent developments in signal analysis techniques have led to major advances in our understanding of animal vocal communication (Boersma and Weenink, 2009; Taylor et al., 2010; Taylor and Reby, 2010). For example, the source–filter theory, which was originally developed to describe the link between parameters of the human voice and their mode of production, has recently been applied to animal vocalisations. This framework has allowed researchers to describe in detail the structure and variation of the acoustic parameters present in animal vocalisations (Briefer and McElligott, 2011b; Fant, 1960; Taylor and Reby, 2010; Titze, 1994).

The source–filter theory of voice production (Fant, 1960; Titze, 1994) states that mammal vocalisations are generated by vibrations of the vocal folds ("source"). This source sound is subsequently filtered by the vocal tract ("filter"). The source determines the fundamental frequency (also known as pitch; "F0"). Fundamental frequency can vary between individuals, as a result of differences in the way that larynx is operated, or because of variation in the morphology of callers (McComb and Reby, 2005; Reby and McComb, 2003). In the supra-laryngeal vocal tract (i.e. the tube that links the larynx to the mouth and nasal openings), certain frequencies of the source spectrum, which correspond to the vocal tract resonances, are selectively amplified or "filtered". The physical characteristics of the filter, such as length and shape of the cavities of the vocal tract, pharynx, mouth and nasal cavities, determine the frequencies of the formants and the relative energy distribution in the spectrum (McComb and Reby, 2005; Taylor and Reby, 2010).

Variation in vocal parameters related to the source or filter encodes information such as mate quality, social status, and individual identity. For example, fundamental frequency varies between individuals in fallow deer female contact calls (*Dama dama*, Torriani et al., 2006). Formant frequencies are important for individuality coding in African elephants (*Loxodonta africana*; McComb et al., 2003), whereas both source and filter-related parameters encode individual identity in goats (Briefer and McElligott, 2011a). Overall, the source–filter framework also has great potential as a valuable tool in animal applied sciences, helping to highlight animal welfare indicators in vocalisations (Briefer, 2012; Briefer et al., 2015; Manteuffel et al., 2004; Marchant-Forde et al., 2002; Watts and Stookey, 2000).

It is highly likely that the acoustic structure of cattle vocalisations provides information about the caller, such as age, sex and individuality, in the same way as vocalisations of other ungulates (Briefer and McElligott, 2011a,b; Fitch, 1997; Reby and McComb, 2003). It has previously been suggested that cattle vocalisations differ among individuals and populations (Hall et al., 1988; Kiley, 1972). Kiley (1972) suggested that cattle produce six different call types in various behavioural contexts. However, the proposed call classification of Kiley (1972) was limited by the technologies for sound recording and analyses that were available at that time.

The assessment of animal welfare is usually achieved through measurements of different physiological or behavioural indicators, in order to obtain information about how well or poorly animals are coping with their environment (Broom, 1986; Boissy et al., 2007). There is evidence suggesting that vocalisations in cattle may signal the physiological and emotional state of the producer (Watts and Stookey, 2000). For example, both cows and calves increase their calling rate after being separated from each other (Kohari et al., 2014; Weary and Chua, 2000), and during handling (Grandin, 1998, 2001; Watts and Stookey, 2001). Similarly, vocalisation structure may vary according to the stress levels of the producer (Stehulova et al., 2008; Thomas et al., 2001; Watts and Stookey, 1999). These studies have demonstrated the potential use of cattle vocalisations to assess stress and welfare (Manteuffel et al., 2004; Thomas et al., 2001; Watts and Stookey, 2000). Therefore, vocal parameters could serve as a useful non-invasive means to assess welfare in cattle (Briefer, 2012; Manteuffel et al., 2004; Weary and Fraser, 1995). However, in order to develop robust vocal welfare indicators, a comprehensive study of cattle vocalisations living in relatively undisturbed conditions (e.g. free-ranging) is required. First,