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Validity and reliability of cardiac measures during behavioural tests in pet dogs at home

Rian C.M.M. Lensen[a], Cécile Betremieux[b], Valérie Bavegems[c], Stanislas U. Sys[d], Christel P.H. Moons[e], Claire Diederich[a,*]

[a] University of Namur, Department of Veterinary Medicine (IVRU), Rue de Bruxelles 61, B-5000 Namur, Belgium
[b] University of Paris 13, Villetaneuse, France
[c] Ghent University, Department of Small Animal Medicine and Clinical Biology, Salisburylaan 133, B-9820 Merelbeke, Belgium
[d] Ghent University, Department of Large Animal Internal Medicine, Salisburylaan 133, B-9820 Merelbeke, Belgium
[e] Ghent University, Department of Nutrition, Genetics and Ethology, Heidestraat 19, B-9820 Merelbeke, Belgium

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ABSTRACT

Behavioural tests are often used to describe dogs' responses to a variety of stimuli. However, the expressed behaviours do not always give an accurate indication of the dogs' mental state. Cardiac measures can be recorded in parallel to the behavioural test to provide additional information about arousal level. Heart rate (HR) reflects the combination of sympathetic and parasympathetic stimulation, whereas the beat-to-beat variation in heart rate (heart rate variability: HRV) provides more details about the balance between sympathetic and parasympathetic activation. In studies validating cardiac measures typically the dog's movement is controlled or the response to only one stimulus at a time is tested. In this study, the validity and reliability of cardiac measures were tested during a behavioural test at home (N = 18 shepherd dogs). HR, HRV and behaviour were recorded in six randomised subtests, in which stimuli of different emotional valences were presented (neutral, positive, negative). Positive and negative subtests differed significantly from the neutral subtests in terms of HR and behaviour ($P = 0.000$). Compared to the neutral subtests (77.85 ± 21.00 bpm), HR was increased (positive: 91.67 ± 21.64 bpm; negative: 100.29 ± 18.54 bpm), and the dogs showed more interactions with the presented stimuli (contact/avoid, approach, look), more oral behaviours and were more active (walk, stand, less lying). However, HR only significantly correlated with activity during the neutral subtest ($r = 0.511$, $P = 0.030$). Hence, activity only appeared to influence HR in the absence of significant emotional stimuli, whereas the increased HR in both the positive and negative subtests reflected arousal. This is supported by the fact that stress-related behaviours and HR were similar in dogs tested a second time (test-retest reliability; N = 15 dogs), despite significant differences in activity between both test moments ($Z = -2.510$; $P = 0.009$). For the HRV variables, on the other hand, no significant differences were found between subtests of different emotional valences. This was possibly caused by errors in recording, due to poor electrode conduction caused by movement of the dogs. In conclusion, this study showed that HR can be a useful measure of arousal during behavioural tests, though it did not allow for a distinction between positive and negative emotional valences. HRV appeared more difficult to record (with the Polar® RS800CX with Wearlink) during constant movement of the dog.

1. Introduction

Behavioural tests are used for a wide range of purposes, including assessment of a dog's working propensity (Batt et al., 2008; Svartberg, 2002), prediction of (un)desirable behaviour (Dowling-Guyer et al., 2011; van der Borg et al., 2010) or fundamental research (Åkerberg et al., 2012; Gácsi et al., 2004). In essence, they assess dogs' behavioural responses in reaction to a variety of stimuli. However, the observed behavioural response does not always accurately reflect the emotional state of the dog (Koolhaas et al., 2007; Paul et al., 2005), and may vary according to context (Beerda et al., 1998). For example, a fearful dog might respond to an aversive stimulus both by active avoidance or tonic immobility (King et al., 2003; Vas et al., 2005). Also, the interpretation of the behaviours may vary based on the scoring system used and the observer's experience (Pastore et al., 2011; Wilsson and Sinn, 2012).

Abbreviations: bpm, beats per minute; HR, heart rate; HRV, heart rate variability; IBI, interbeat interval.

* Corresponding author at: University of Namur, Département de Médecine Vétérinaire–URVI, Rue de Bruxelles 61, 5000, Namur, Belgium.
E-mail address: claire.diederich@unamur.be (C. Diederich).

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Physiological measures provide additional insights into the dog's psycho-physiological response to environmental stimuli, or 'arousal' (Mills et al., 2010). When an animal encounters an environmental challenge, based on the emotional appraisal of that stimulus, the body will mobilise energy through the activation of several neurobiological systems. This results in an increased heart rate, blood pressure and increased corticosteroid production (Mills et al., 2010). Hence, arousal is reflected by short-term increases in cortisol levels in blood or saliva (Haubenhofer and Kirchengast, 2006; Hennessy et al., 1998), but such measures only give an indication of these marker concentrations at the sampling moment. Blood pressure is also measured instantaneously and multiple repetitions are necessary to obtain accurate results (Rattez et al., 2010). Heart rate measures, on the other hand, can be obtained in real-time during a behavioural test, allowing direct assessment of the immediate physiological reaction to a stimulus.

Heart rate (HR) is regulated both by the sympathetic and parasympathetic nervous system: stimulation by sympathetic nerves increases HR, whereas stimulation by the vagal nerve generally causes it to decrease (von Borell et al., 2007). However, physical activity may also increase HR (Maros et al., 2008; Palestrini et al., 2005), and acts as a confounding variable in behavioural tests where dogs move around freely. Heart rate variability (HRV), describing the beat-to-beat variation in heart rate (Geisler et al., 2010), has been shown to be a more robust measure in relation to physical activity (Bergamasco et al., 2010; Maros et al., 2008). Compared to HR, which only represents the resultant effects of vagal and sympathetic regulation, HRV provides a more detailed image of the regulatory characteristics of the autonomic nervous system. Low HRV has been associated with negative emotional states, whereas positive states are generally associated with high HRV, caused by a high vagal tone (reviewed by Bergamasco et al., 2010; Boissy et al., 2007; von Borell et al., 2007). However, the analysis of HRV is more complex than that for HR and requires minimum recording intervals of one to five minutes, depending on the analysed HRV parameter (Task Force, 1996; von Borell et al., 2007).

In studies validating cardiac measures typically the dog's movement is controlled (Essner et al., 2013; Jonckheer-Sheehy et al., 2012) or the response to only one stimulus at a time is tested (Beerda et al., 1998; King et al., 2003). Little information is available about the validity and reliability of cardiac measures during a behavioural test in which the dogs are exposed to a variety of stimuli and are allowed to move freely (e.g., Bergamasco et al., 2010; Palestrini et al., 2005).

This study assessed the validity and reliability of cardiac measures during a behavioural test at home. If cardiac measures reflect arousal, a significant change in HR and HRV could be expected in response to stimuli inducing an emotional response, compared to neutral situations. In addition, lower HRV (sympathetic dominance) could be expected in response to stimuli with a negative emotional valence, compared to stimuli with a positive emotional valence. On the other hand, if cardiac measures are influenced by activity, associations between cardiac measures and activity would be expected, regardless of the stimuli presented to the dogs. Finally, test-retest reliability was assessed to determine the consistency of cardiac responses over time.

2. Material and methods

2.1. Subjects

Dog owners were recruited at the University of Namur (Belgium), by advertisements in the town centre and via social networks. To minimise breed-related influences, only breeds of the herding group (American Kennel Club, 2016) were chosen for this study: nine Border collies, five German shepherd dogs, one miniature American shepherd and three crossbreeds (8 males; 10 females). Only sexually mature dogs were included (age: 1–11 years; mean ± SD: 3.9 ± 2.8 years) to minimise differences between dogs in terms of neuroendocrine development (Fratkin et al., 2013). None of them had any history or current evidence of cardiovascular disease.

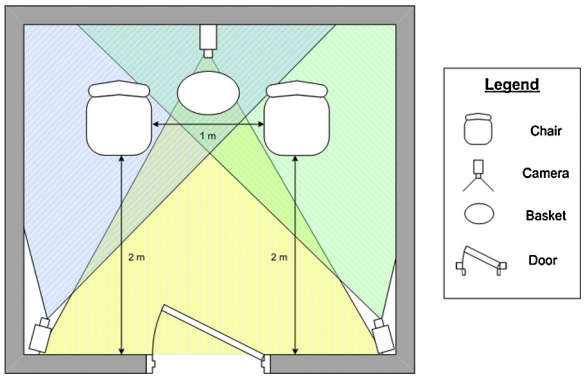

Fig. 1. Schematic overview of the test room set-up. The room was familiar to the dog and gradually prepared by the owner from a few days before the test.

2.2. Data collection

2.2.1. Behavioural test

The dogs were tested at home in a room to which they usually had access, to minimise influence of unfamiliar settings on behaviour and cardiac activity (Dreschel and Granger, 2005). The owners were instructed to prepare the test room gradually from a few days before the test, to prevent abrupt changes in the dog's living environment (Fig. 1). On the test day, the tester (CB) visited the dog's home 30 min prior to the test to set up the video cameras and to let the dog get used to her presence. After this period, baseline cardiac activity and behaviour were recorded for five minutes (see Section 2.2.2. *Cardiac measurements*), for the sole purpose of verifying whether the 'neutral' subtests (described below) were indeed comparable to a casual situation in which no standardised stimuli were presented to the dogs. Then, six different subtests were conducted in a random order, during which stimuli of different emotional valences were presented (Table 1). Different types of stimuli were chosen to account for possible individual-related differences in perception of the stimulus (Appleby and Pluijmakers, 2003). A ball had been used in a previous study to validate cardiac measures in dogs, and induced significant increases in HRV (Maros et al., 2008), so this was considered a 'positive' stimulus (Bergamasco et al., 2010; Boissy et al., 2007; von Borell et al., 2007). The prospect of going for a walk is also generally considered to be positive, and a study by Pongrácz et al. (2005) showed that this induced similar vocalisations as in a play setting. A remote-controlled car and umbrella were considered 'negative' (aversive) stimuli, as they induced responses of avoidance, lowered posture and restlessness (Beerda et al., 1998; King et al., 2003). Due to the startling nature of the umbrella (suddenly opened), this stimulus was always presented at the end of the test, giving the dog ample time to recover. Also, two 'neutral' subtests were designed not to elicit any significant emotional response (Bloom and Friedman, 2013).

Each subtest lasted for one minute (following King et al., 2003), after which the tester removed the stimulus and remained passive for four minutes. This five-minute interval was chosen to minimise carry-over effects of the preceding subtest and to provide a sufficient interval for measuring heart rate variability (see Section