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Research Paper

# Phenotypic determination of noise reactivity in 3 breeds of working dogs: A cautionary tale of age, breed, behavioral assessment, and genetics

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ABSTRACT

Noise reactivity is a common problem for dogs and may progress to true phobia. Survey studies report that some type of noise reaction occurs in up to half of all pet dogs throughout their lifetimes, indicating that noise reactivity and/or phobia is a welfare issue. Familial aggregations of affected dogs have been reported, and increased prevalence in certain breeds has been suggested. Reactivity to noise can severely compromise function in both pet and working dogs. Noise reactivity may be comorbid with many anxiety disorders for both canines and humans and is postulated to effect information processing in associated human, rodent, and dog conditions. Any putative effect of noise on information processing becomes a concern for problem solving and other aspects of cognition that are important to working dogs. Accordingly, we sought to phenotype 3 breeds of herding dogs commonly used for work as detection dogs, police and/or patrol dogs, search and rescue dogs, and/or service dogs: Australian shepherds (AUS), border collies (BOC), and German shepherds (GSD). We analyzed demographic information and behavioral responses to noises (guns, storms, and fireworks) known to provoke fearful or phobic responses for 59 AUS, 81 BOC, and 58 GSD, who were also included in a genetic analysis. Behaviors were compared using a metric constructed from information on type, frequency, and intensity of response, and the Anxiety Intensity Rank (AIR) score. Reactivity to noise was found to segregate in some family lines for the dogs in this study, although individuals expressed considerable variation in noise response. Such variation may be time and exposure dependent and presents a phenotyping challenge. In this study, the presence and intensity of reactivity as represented by AIR scores varied by breed but only slightly with age. The BOC studied were older, and BOC and AUS were more severely affected (higher AIR scores) than were GSD. Source and/or purpose of dog may also affect severity of affliction. Determination of crisp and accurate phenotypes is essential for understanding underlying genetic contributions. For noise reactivity and/or phobia, accurate phenotypes include age of onset and specific behavioral characterization. Standardized and objective assessments are essential for assessment of progression and comorbidity. Our data imply that accurate phenotypic assessment is possible at a relatively early age, providing for both humane treatment and accurate phenotyping that facilitates good genotyping.



## Introduction

Noise reactivity and phobia are common pathologic behavioral conditions in pet dogs. Many surveys report that up to 50% of dogs may be affected by some extreme reaction to some noise during their lifetime (Blackshaw et al., 1990; Dale et al., 2010; Blackwell et al., 2013; Storengen and Lingaas, 2015; Tiira and Lohi, 2015, 2016). Reactions are most commonly reported for storms, fireworks, and guns, but noises associated with vehicles, machines, alarms, and others can also trigger fearful, anxious, or phobic responses in dogs (McCobb et al., 2001; King et al., 2003; Ley et al., 2007).

A number of other terms are often used to describe an adverse reactive, fearful, or phobic response, including noise aversion, noise

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fear, noise stress, storm or thunderstorm phobia, and noise sensitivity. Necessary and sufficient criteria for labeling a dog noise reactive or phobic or any of these other terms neither are usually included in most studies (but see, Overall et al., 2001; Dreschel and Granger, 2005) nor are the range of behaviors potentially displayed by the afflicted dog often noted (but see Overall et al., 2001; Crowell-Davis et al., 2003; Tiira and Lohi, 2015; Tiira et al., 2016). Without standardized and discrete diagnostic criteria as well as unbiased and quantifiable behavioral assays for such criteria, we greatly diminish the possibility of understanding and identifying true familial, breed, and population associations for any behaviors that are problematic for dogs because we cannot recognize dogs that are more similar or dissimilar (Overall, 2005; Overall et al., 2014; Tiira and Lohi, 2015; van Rooy et al., 2014).

Diagnostic criteria also permit discrimination of behavior patterns that are a manifestation of normal behavior from those displayed as a manifestation of abnormal and pathologic behavior. Some response to an acute stressor is normal and adaptive, and such responses are characterized by recovery with a return to the individual's baseline of behavior. Pathologic responses include those that are out of context to the stimulus where signs of acute stress are excessive in duration and/or intensity and become more so with each exposure until an extreme plateau is reached. Spontaneous recovery is absent in pathologic responses. This distinction between normal and abnormal or pathologic is essential because the misinterpretation of canine behavior by humans is common (Haverbeke et al., 2008; Tami and Gallagher, 2009; Kuhne et al., 2012a,b; Wan et al., 2012; Bloom and Friedman, 2013; Kuhne et al., 2014; Foyer et al., 2015), and owners do not recognize subtle signs of anxiety (Mariti et al., 2012). An owner judgment about undefined anxiety, fear, and aggression in a survey questionnaire, especially one using a Likert scale (Hsu and Serpell, 2003; Temesi et al., 2014), is impossible to validate (Diederich and Giffoy, 2006; van Rooy et al., 2014) and is void of information pertaining to behavioral heterogeneity that can allow us to study mechanism.

We propose that it is possible to create objective assessments of behavior that are void of judgment and use clear terminology (Overall et al., 2001; Crowell-Davis et al., 2003; Overall et al., 2006a,b; Tiira et al., 2014). It is possible to identify observable criteria associated with the dog's indication that he is reacting to a stressor (here, noise) and to evaluate those criteria in terms of intensity, frequency, duration, and specific response, as we have done here. Assessment of phenotypes can only elucidate genetic studies if the behavioral criteria used are clear, crisp, and accurately reflect and discriminate among the behaviors exhibited by the dogs.

The diagnostic criteria used here were validated in a clinical study of noise phobia (Overall et al., 2001) and require that noise-phobic dogs exhibit a profound, nongraded, and extreme response to noise manifest as intense avoidance, escape, or anxiety and associated. Such signs are associated with the sympathetic branch of the autonomic nervous system and triggered by reactivity in the locus ceruleus (LeDoux, 2000; Tully and Bolshakov, 2010). Dogs who are characteristically distressed when exposed to specified noises, including storms, but who do not meet the criteria for a phobia may be classified as reactive (Overall, 2013). We chose the term 'reactive' rather than 'sensitive' (Sherman and Mills, 2008; Tiira et al., 2016) because sensitive may imply, could be confounded with, and is commonly used to describe attributes of auditory capability, for which we have no data (but see Scheifele et al., 2016). The term 'reactive' implies no underlying mechanism, merely a lowering of threshold for the behavioral response.

The behavioral signs of distress associated with noise reactivity and phobia are nonspecific but can be benchmarked and quantified. These signs may include trembling, freezing, panting, social withdrawal, pacing, salivating, urinating, defecating, destruction (with or without self-injury), hiding and/or crouching (includes body lowering and tail tuck postures), and escape and/or running away behaviors (with or without self-injury) (Schull-Selcer and Stagg, 1991; Beerda et al., 1997, 1998; Overall et al., 2001; Crowell-Davis et al., 2003; Hydbring-Sandberg et al., 2004; Sherman and Mills, 2008; Cracknell and Mills, 2011), which are all classic responses to anxious states and represent an acute stress response. These are all signs of anxiety that owners can recognize and use to tell when their dog is distressed (Mariti et al., 2012).

Dogs exhibiting these anxious and panicky signs in response to a noise stimulus experience both physical and behavioral debility and compromise (Dykman et al., 1966; Murphree et al., 1967; Overall et al., 2001; Dreschel and Granger, 2005; Dreschel, 2010; Siniscalchi et al., 2013). Noise reactivity and phobia interferes with performance in working dogs (Tomkins et al., 2011, 2012; Gazzano et al., 2007; Batt et al., 2008; Asher et al., 2013; Burghardt, 2013; Arvelius et al., 2014; Sherman et al., 2014; Evans et al., 2015) and interferes routine patterns of daily life in pet dogs (Overall et al., 2001; Crowell-Davis et al., 2003; Gruen and Sherman, 2008; Cottam et al., 2013). Noise reactivity and phobia is associated with patterns of brain organization (Branson and Rogers, 2006; Francks et al., 2007; Siniscalchi et al., 2008; Foler et al., 2011), which may be one mechanism through which pathologic changes occur.

Similar patterns pertain in other species. In rats, performance in maze tests (number of errors, time to goal, and number of rearings) was impaired when the rats were exposed to loud noise (100 dB background noise level, the low end of noise estimates for the stimuli in this study; http://www.noisehelp.com/noise-level-chart.html), and neurons in the hypothalamic paraventricular nucleus, central nucleus, and basolateral nucleus of the amygdala, regions associated with stress, were activated (Amemiya et al., 2010). Chronic and acute noise stresses produced differential responses in the hippocampus but similar responses in the hypothalamus, suggesting that behavioral effects can be influenced by exposure (Eraslan et al., 2015). Noise stress (105 dB) has been shown to impair high-order, prefrontal cortex, and delayed-response performance in cognitive trials in monkeys (Arnsten and Goldman-Rakic, 1998; Arnsten, 2009). Babisch (2003) noted that noise activates sympathetic responses and stimulates epinephrine, norepinephrine, and cortisol, all hormones associated with stress. Acute noise stress in humans has been shown to impair cognitive control in the anterior cingulate cortex (Banis and Lorist, 2012).

Pathologic noise reactions in dogs worsen quickly with exposure, suggesting that adverse effects on mental and physical health are long term and may be more profound than usually appreciated. Many of these reactions may be modulated by changes in glucocorticoid receptor regional activity and subsequent molecular processes that adversely affect both cognitive ability and retrieval and use of memory (Popoli et al., 2011; Nasca et al., 2015; Jasnow et al., 2016; Rogerson et al., 2016). Noise phobia is considered a commonly comorbid condition (affecting both general fears (Tiira and Lohi, 2016)) and specific conditions like separation anxiety (Overall et al., 2001). When noise phobia is comorbid, the signs of each condition are worse than for canine patients with a single anxiety-related condition (Overall et al., 2001), suggesting that the noise pathology, itself, changes the underlying neurochemical or neuronal reactivity. Comorbid conditions in humans and other primates show similar patterns of effect where signaling in the amygdala, hippocampus, and frontal cortex can be impaired in response to repeated stress signaling (Arnsten and Goldman-Radic, 1998; Arnsten 2009).

## Materials and methods

Dogs of the 3 breeds studied (59 Australian shepherds [AUS], 81 border collies [BOC], and 58 German shepherds [GSD]) were