UNIVERSITY OF LJUBLJANA
BIOTECHNICAL FACULTY

Elena GOBBO

MECHANISMS OF AGGRESSIVE BEHAVIOUR IN DOGS

DOCTORAL DISSERTATION

Ljubljana, 2022

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MEHANIZMI AGRESIVNEGA OBNAŠANJA PRI PSIH

DOKTORSKA DISERTACIJA

Ljubljana, 2022

Based on the Statute of the University of Ljubljana and the decision of the Biotechnical Faculty senate, as well as the decision of the Commission for Doctoral Studies of the University of Ljubljana adopted on 24 September 2019 it has been confirmed that the candidate meets the requirements for pursuing a PhD in the interdisciplinary doctoral programme in Biosciences, Scientific Field Animal Science. Assoc. Prof. Manja Zupan Šemrov is appointed as supervisor.

Na podlagi Statuta Univerze v Ljubljani ter po sklepu Senata Biotehniške fakultete in sklepa Komisije za doktorski študij Univerze v Ljubljani z dne 24. 9. 2019 je bilo potrjeno, da kandidatka izpolnjuje pogoje za opravljanje doktorata znanosti na Interdisciplinarnem doktorskem študijskem programu Bioznanosti, znanstveno področje znanost o živalih. Za mentorico je bila imenovana izr. prof. dr. Manja Zupan Šemrov.

Supervisor (mentorica):	Assoc. Prof. Dr. Manja ZUPAN ŠEMROV University of Ljubljana, Biotechnical Faculty, Department of Animal Science

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AB In order to investigate the mechanisms associated with dog aggression using a multidisciplinary approach, four separate studies were conducted as part of this thesis. In the first study, retrospective questionnaire data were used to determine the contextual aspects of dog bites and revealed a high incidence of bites during unintended interaction with the biting dog. The second study examined psychosocial factors using a combination of behavioural tests and questionnaires reported by dog owners. Low sociability in dogs and high neuroticism in owners, as well as high avoidant and low anxious attachments between owner and dog were the characteristics associated with dog aggression. In the third study, three behavioural tests were used to examine the association between two different aspects of inhibitory control and aggression. Impaired self-control, measured as performance on the delay of gratification test, but not cognitive inhibition, measured as performance on the reversal learning test, was found to be associated with aggressive biting behaviour. In the final study, behavioural responses and several physiological changes were examined simultaneously and in real-time. Aggressive dogs were found to have decreased salivary serotonin concentration and increased facial surface temperature. In addition, frequent tail wagging and a tendency to wag the tail to the left during aggression were observed for the first time. Through new or improved approaches, our findings contribute to a better understanding of dog aggression, and may benefit not only the scientific community, but also the general public.

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AI Za ocenjevanje mehanizmov, povezanih s pasjo agresijo, so bile z uporabo multidisciplinarnega pristopa v okviru te disertacije izvedene štiri ločene študije. V prvi študiji je bil za določitev kontekstualnih vidikov pasjih ugrizov uporabljen retrospektivni vprašalnik. Razkril je visoko incidenco ugrizov med nenamerno interakcijo z ugrizlim psom. Druga študija je s kombinacijo testiranja obnašanja in vprašalnikov, ki jih je izpolnil lastnik, raziskovala psihosocialne dejavnike. Nizka družabnost pri psih, visok nevroticizem pri lastnikih ter visoka izogibajoča navezanost lastnika in psa ter nizka anksiozna navezanost lastnika in psa so bile lastnosti, povezane z agresijo psov. V tretji študiji je bila s tremi testi obnašanja raziskana povezava med dvema različnima vidikoma inhibicijske kontrole in agresije. Izkazalo se je, da je oslabljen samonadzor, merjen kot uspešnost pri nalogi zapoznelega nagrajevanja, vendar ne tudi kognitivna inhibicija, merjena kot uspešnost pri nalogi obratnega učenja, povezana z agresivnim grizenjem. V zadnji študiji so bili sočasno in v realnem času preučeni obnašanje in več fizioloških sprememb. Ugotovljeno je bilo, da so imeli agresivni psi znižano koncentracijo serotonina v slini in povišano površinsko temperaturo obraza. Med to študijo sta bila tudi med agresijo prvič opažena pogosto mahanje z repom in nagnjenost k mahanju repa v levo stran. Z uporabo novih ali izboljšanih pristopov so te ugotovitve pomembne za nadaljnje razumevanje agresije pri psih. Z novimi ali izboljšanimi pristopi naše ugotovitve izpopolnjujejo razumevanje agresije psov in lahko koristijo ne le znanstveni skupnosti, ampak tudi širši javnosti.

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1 PRESENTATION OF THE PROBLEM AND HYPOTHESES

1.1 SPECIFICATION OF THE RESEARCH PROBLEM

Aggression can be observed in a variety of animal species, including dogs. It is a behaviour that threatens or inflicts physical or psychological pain (Anderson and Bushman, 2002). In humans, it can be further categorized as physical aggression, when the harmful behaviour results in pain or injury, or verbal aggression, when there is a harmful threat (Buss, 1961). Similarly, dog aggression can be grouped and expressed as the aggressive biting behaviour, by snapping, attacking or attempting to bite, and the aggressive threatening behaviour, by growling, barking and baring teeth (Netto and Planta, 1997). Other behavioural possibly indicative of aggression include staring, freezing, tail lifting, closed mouth with pursed lips, etc. (Christensen et al., 2007). Aggression can also be categorized based on the assumed internal motivation of the dog, for example territorial-, fear-, possessiveness- and dominance related aggression or more objectively, by target, as stranger-, owner-, and dog-directed aggression (Houpt, 2006).

Although it is part of the normal behaviour of dogs (Netto and Planta, 1997), the level of aggression in individual dogs may be so high that it is unacceptable to the immediate environment or to society in general, due to the close relationship and coexistence with humans. It is considered one of the most common and dangerous behavioural problems in dogs, especially when it is directed towards owners or other people (Casey et al., 2014; Flint et al., 2015). Dog owners often do not have sufficient knowledge regarding safe interaction with dogs and identification of warning signals of aggression (Reisner and Shofer, 2008). Often, parents do not provide appropriate education, supervision and intervention when their children interact with dogs (Arhant et al., 2016). For this reason, a significant number of people, mostly children, are bitten by a dog every year and bites can have different consequences. A large number of bitten people need to seek professional medical help, and more severe bites can lead to hospitalization, physical and social handicap or even victim's death, making dog bites a public health problem (Súilleabháin, 2015; Mora et al., 2018). Aggressive behaviour is also a common reason for dogs being relinquished to animal shelters, abandoned, or euthanized (Salman et al., 2000; Diesel et al., 2008), making the consequences of dog aggression an animal welfare and human-animal interaction issue.

There are individual differences in how dogs express or inhibit behavioural responses in the environment. These responses can be associated with a number of internal and external factors (Haug, 2008), as measured by physiological changes, behavioural measures and owner reports. Each methodological approach has its advantages and disadvantages. For example, owner reports, despite involving people that are familiar with the dog's everyday behaviour (Hsu and Serpell, 2003), include owners that have limited knowledge regarding dog behaviour or its interpretation and can be influenced by owner's bias (Wiener and Haskell, 2016). On the other hand, behavioural observations, especially behavioural tests are time consuming and allow smaller and less diverse sample (Hsu and Serpell, 2003). Moreover, while observing physiological changes, especially during real-time behaviour, it is important to measure multiple physiological parameters simultaneously (Reefmann et al., 2009) and non-invasively, to avoid the influence of measuring devices on the behavioural responses (Ermatinger et al., 2019). For these reasons, the investigation of mechanisms of aggression in this thesis involves a combination of different methodological approaches and simultaneous measurement of different physiological parameters. We started by exploring external factors, focusing on the contexts of dog bites, then moved to psychosocial and cognitive aspects and concluded with physiological aspects. The following chapters present these main aspects of dog aggression, studied in this thesis.

1.1.1 Contexts, dogs' and dog bite victims' characteristics

While focusing on biting behaviour only, previous studies reported on the characteristics of the dogs involved, suggesting large, adult males, known to the victim to be the most common (Rosado et al., 2009; Sarcey et al., 2017; Oxley et al., 2018). There is a wide variety of breeds commonly involved in biting incidents, from larger breeds such as German Shepherds, Rottweilers (Sarcey et al., 2017; Oxley et al., 2018), and Belgian Shepherds (Cornelissen and Hopster, 2010), to smaller breeds such as Jack Russell Terriers (Cornelissen and Hopster, 2010), Shih Tzus (Messam et al., 2012) and English Cocker Spaniels (Fatjó et al., 2007). Bites from larger breeds are often reported when observing hospital data, while bites from smaller breeds may also be common, but victims often do not seek medical attention (Westgarth et al. 2018). Children (Súilleabháin, 2015), particularly boys (Basco et al., 2020), are the most common victims of dog bites and resulting injuries can range from superficial wounds, to severe injuries, as children are often bitten on the face, neck and head (Morgan and Palmer, 2007). The prevalence of dog bites decreases with age and the fewest bites are observed in older adults (Quirk, 2012). Similarly, as in children, males are more likely to be involved in a biting incident than females in adults (Súilleabháin, 2015; Westgarth et al., 2018).

In terms of the environment in which biting incidents occur, previous data suggest that non-public areas, mainly outside or inside a residential area are the most common (Cornelissen and Hopster, 2010; Oxley et al., 2018). A large proportion of children under the age of four are bitten at their own homes (De Keuster et al., 2006). Positive and negative contact activities with the dog, such as petting, playing (Horisberger et al., 2004; Cornelissen and Hopster, 2010; Oxley et al., 2018) or manipulation of the dog in an aversive manner (Rosado et al., 2009) appear to be the most commonly reported contexts for dog bites. Often, even a change in body posture or eye contact can trigger an aggressive response (Reisner et al., 2007). Nevertheless, these descriptions of dog bite incidents are found in only few studies (Westgarth and Watkins, 2015; Oxley et al., 2018; Owczarczak-Garstecka et al., 2018a, Owczarczak-Garstecka et al., 2018b) based on a limited sample size. This means that most studies lack a thorough description of dog bites and detailed information about the circumstances of the interaction or attempted interaction, especially prior to the incidents, as well as a precise description of the location where the bite occurred. There is also a lack of information such as the restriction of movement of the dog and more detailed information about the dogs involved, such as their housing conditions, prior socialization, origin, training history, etc.

1.1.2 Psychosocial effects

The study of psychosocial effects related to aggression has shown that some psychosocial aspects of dogs and owners may be associated with aggressive behaviour in dogs. The first aspect is dog personality, defined as inter-individual behavioural traits that are consistent over time and across contexts (Fratkin et al., 2013). Animal personality is usually assessed using standardized tests (Dingemanse and Wolf, 2010). One of the most used tests in dogs is the Dog Mentality Assessment (DMA) (Svartberg and Forkman, 2002). During DMA, by observing dog’s reaction to external stimuli, the dogs are scored on five personality traits; playfulness, curiosity/fearlessness, chase-proneness, sociability, aggressiveness, and a broader dimension named shyness/boldness (Svartberg and Forkman, 2002). Another commonly used methods for assessment of dog personality are owner-reported questionnaires (Jones and Gosling, 2005). Their use revealed that less sociable dogs tended to show higher levels of aggression towards children and strangers (Kaneko et al., 2013) and that more fearful dogs showed more fear-related aggression and dog-directed aggression (Haverbeke et al., 2009; Arata et al., 2014).

Next to dog’s personality traits, the owner’s personality also has an important influence on dog’s behaviour, as the human factors have greater impact on the dog-human relationship than dog factors (Meyer and Forkman, 2014). This phenomenon may be due to cohabitation and shared activities, leading to emotional contagion, or due to owner’s selecting dogs that matches their personality and lifestyle, as seen in humans (Tidwell et al., 2013). Human personality is most commonly assessed using the Big Five factor taxonomy, which identifies five personality traits (extraversion, conscientiousness, neuroticism, agreeableness, and openness) (Rammstedt and John, 2007). Moreover, Turcsán et al. (2012) found a positive correlation between owners and dogs in all five investigated personality traits. Regarding dog aggression, previous studies have shown that dogs whose owners have lower scores for agreeableness, emotional stability, extraversion and conscientiousness show greater aggression toward their owners and fear of strangers (Dodman et al., 2018).

Another human factor that can potentially influence dog behaviour is attachment. Attachment is a cognitive-emotional bond that was first used to describe the affectional bond between human children and caregivers and later between humans and places, objects and non-human animals (Bell and Spikins, 2017; Meehan et al., 2017), including dogs (Archer and Ireland, 2011). There are secure and insecure attachment types. When the attachment between two individuals is categorized by trust and comfort with intimacy, it can be described as secure. In contrast, two types of insecure attachment, anxious and avoidant attachment, can be defined by controlling behaviour and avoidance of intimacy, respectively (Beck and Madresh, 2008). Attachment has not yet been studied in the relation to dog aggression, but it has been previously reported that owners' attachment styles play a role in the occurrence of different behavioural strategies in their dogs during aversive situations (Rehn et al., 2017) and occurrence of behavioural problems in dogs (Konok et al., 2015).

To date, psychosocial factors, that play or may play a role in dog aggression, have only been assessed using owner-reported questionnaire data and attachment styles have not yet been studied in this context. As mentioned above, due to limitations of owner reports, for more objective and comprehensive assessment of psychosocial effect, the combination of different research methods, for example behavioural testing conducted by professionals in the field and questionnaire-based assessment by the owners, is needed.

1.1.3 Cognitive effects

Higher-order cognitive processes, involved in the self-regulation of emotions and actions, including aggression, can be referred to as executive control (Séguin and Zelazo, 2005). One of the proposed processes is inhibitory control, defined as an individual ability to block an immediate response in favour of a delayed but more appropriate behaviour (Bray et al., 2014), and has previously been associated with aggression in human adults (Anderson and Bushman, 2002; Hsieh and Chen 2017) and children (Raaijmakers et al., 2008). In dogs, inhibitory control has not yet been studied in relation to dog aggression, but it has been previously reported that dogs have the ability to inhibit behavioural responses that are unwanted by their owners (Gácsi et al., 2009). In addition, it has been suggested that cognitive impairments (Denenberg et al., 2014) and owner-reported trait impulsivity (Wright et al., 2011) play a role in dog aggression.

Inhibitory control is not a unitary mechanism, but a collection of distinct cognitive processes (Beran, 2015; Brucks et al., 2017). In dogs, it is usually assessed with different cognitive tests (Bray et al. 2014; Brucks et al., 2017; Vernouillet et al., 2018), each targeting separate aspect of this ability. Motor inhibition, cognitive inhibition and self-control are the three most commonly assessed aspects of inhibitory control in dogs (Brucks et al., 2017; Brucks et al., 2019). Two of these aspects, self-control and cognitive inhibition, have previously been associated with aggression in humans (Mitchell et al., 2006; Herndon et al., 2015), but research on the association with dog aggression is lacking.

Self-control is defined as the ability to control an impulse response in a tempting situation (Beran, 2015). It can be measured using an exchange paradigm (e.g., delay of gratification) in which an individual must resist immediate gratification for the sake of delayed, but better quality reward (Mischel et al., 1989). This ability to wait is proposed to be an evidence of self-control, because it leads to receiving a better reward in a given situation (Beran, 2015). In addition, it has been suggested that better self-control influences the ability to respond or override the urge to react aggressively (Denson et al., 2012). While this has to yet been explored in dogs, it has been reported in humans (Herndon et al., 2015) and rats (Van den Bergh et al., 2006) that impaired self-control is associated with a more frequent occurrence of aggression.

Cognitive inhibition is defined as the ability to regulate the content of working memory by removing insignificant information in a given situation (Hasher et al., 1999). It can be measured using an object discrimination paradigm, often referred to as reversal learning, during which after an initial discrimination, two stimuli change their reward contingencies (Milgram et al., 1994). During the paradigm, the ability to inhibit a learned response and avoid the previously rewarded option, as well as flexibility in relearning object-reward contingencies, are measured (Milgram et al., 1994; Brucks et al., 2017). Impairments in reversal learning has previously been associated with aggression in humans (Mitchell et al., 2006), whereas the same results have not yet been reported in dogs.

1.1.4 Physiological effects

In the field of physiological research, the authors reported cardiovascular and neuroendocrine changes associated with aggression. Heart rate (HR), heart rate variability (HRV) and skin (surface) temperature are the main studied cardiovascular parameters. Dogs exhibiting reacting behaviour in response to threatening stimuli have been found to have increased HR and decreased HRV (Gácsi et al., 2013), while dogs with history of aggression have lower resting HRV (Craig et al., 2017). Fewer studies have focused on changes in surface temperature related to dog aggression and also other animals. Only Rigternik et al. (2018) observed surface temperature during human-directed aggression and reported no changes between aggressive and non-aggressive dogs. In another study, Boileau et al. (2019)

found decrease in dorsal surface temperature in fighting pigs. The remaining animal studies focused on other negative affective states and reported decreased nasal surface temperature in monkeys during aversive stimuli (Kuraoka and Nakamura, 2011; Ermatinger et al., 2019), decreased periocular area and ocular bulb surface temperature in rabbits during stress (Ludwig et al., 2007) and decreased nasal surface temperature in kennelled dogs (Part et al., 2014). To assess cardiovascular changes during aggression, especially in moving animals, surface temperature measured with infrared thermography seems to be better compared to HR and HRV measures. This is due to many limitations associated with moving artefacts, including displaced HR electrodes leading to false signals (Essner et al., 2015), poor electrodes conduction (Lensen et al., 2017) and intrusive measuring devices, often strapped to the chest of the subject that often require prior training with a dummy monitor (Lensen et al., 2017). In contrast, infrared thermography is non-invasive and can measure physiological changes in real time without potentially altering behavioural responses, making it a suitable tool to for studying aggression in real time.

Regarding the neuroendocrine activations that modulate coping, cognitive and behavioural functions during internal and external stressors, the primary stress hormone cortisol (Veissier and Boissy, 2007) and the inhibitory neurotransmitter serotonin (Summers and Winberg, 2006) are the two commonly observed parameters. The release of cortisol helps the body to remain on high alert and provides the body with energy (Lee et al., 2015), while serotonin plays a role in behavioural inhibition and appropriate behavioural adaptations (Bari and Robbins, 2013). Observing both parameters in humans, Montoya et al. (2012) reported that a high ratio of testosterone and cortisol concentration, along with low serotonin concentration modulates impulsive aggression. Similarly, dogs with owner-reported aggression have been reported to have significantly lower serum serotonin concentration (Çakiroğlu et al., 2007; Rosado et al., 2010; León et al., 2012) and higher plasma cortisol concentration (Rosado et al., 2010) compared to dogs with no history of aggression. To avoid observation of cortisol and serotonin in serum and plasma that requires invasive blood sampling and causes additional stress (Cook, 2012), both parameters can be observed in highly comparable saliva samples showing short-term physiological changes (Lensen et al., 2015). To date, there is lack of simultaneous investigation of aggression related behaviour in dogs and neuroendocrine activation measured non-invasively in real time.

1.2 AIMS OF THE STUDY AND RESEARCH HYPOTHESES

Although dog aggression is a widely recognized problem, there are major knowledge gaps regarding the contextual, psychosocial, physiological, and cognitive factors that mediate this behaviour. The main aim of this thesis is to attempt to provide a comprehensive picture of the mechanisms involved in dog aggression through a combination of different methodological approaches in four separate studies.

In the first study, which used retrospective owner-reported dog biting incidents, we predicted that investigation of larger sample of dog bites that are not limited to a prior dog-human interaction will lead to a greater number of contexts in which dog bites occur, than previously thought (Oxley et al., 2018).

In the second study, based on previous reports using questionnaires only (Kaneko et al., 2013; Arata et al., 2014; Dodman et al., 2018), we predicted that dogs with owner-reported past aggressive behaviour will have higher trait scores for aggressiveness, chase-proneness and lower trait scores for playfulness, curiosity/fearlessness and sociability. In addition, aggressive dogs will be associated with owners with lower trait scores agreeableness, extraversion and conscientiousness and higher neuroticism and attachment scores.

In the third study, based on human studies (Mitchell et al., 2006; Herndon et al., 2015), we hypothesized that dogs with higher aggression level during behavioural testing will show poorer inhibitory control on delay of gratification and reversal learning test.

Our hypothesis in the fourth study was that dogs exhibiting aggressive behaviour during behavioural test would have increased salivary cortisol concentration and decreased salivary serotonin concentration in real time, as has been observed in other studies of dogs with history of aggressive behaviour (Rosado et al., 2010). We also predicted decreased body and facial surface temperature during aggression as observed in similar situations in other species (rabbits: Ludwig et al., 2007; monkeys: Kuraoka and Nakamura, 2011; pigs: Boileau et al., 2019).

2 SCIENTIFIC WORKS

2.1 PUBLISHED SCIENTIFIC WORKS

2.1.1 Factors affecting human-directed aggression resulting in dog bites: contextual aspects of the biting incidents

Gobbo E., Zupan Šemrov M. 2021. Factors affecting human-directed aggression resulting in dog bites: the contextual aspects of the biting incidents. Society & Animals (published online ahead of print), doi: 10.1163/15685306-bja10066: 20 p.

Using a web-based questionnaire with 29 close- and open-ended questions about 400 self-reported dog-biting incidents in Slovenia, this research investigated the contexts of dog bites, focusing on characteristics of the dogs and the descriptions of the situations to identify the main risk factors for the occurrence of dog bites. Even though it has been suggested that most dog bites occur during initially non-aggressive interactions with the dog (e.g., during petting, playing), in our study we discerned a wide variety of contexts, including those in which the person did not intend to interact with the dog. Most victims reported unprovoked bites during fast movements near the dog, while coming into close proximity, and during incidents without a reason. These incidents more likely occurred in public than private places and were associated with purebred dogs with a history of aggression.

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Factors Affecting Human-Directed Aggression Resulting in Dog Bites: Contextual Aspects of the Biting Incidents

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Abstract

Using a web-based questionnaire with 29 close- and open-ended questions about 400 self-reported dog-biting incidents in Slovenia, this research investigated the contexts of dog bites, focusing on characteristics of the dogs and the descriptions of the situations to identify the main risk factors for the occurrence of dog bites. Even though it has been suggested that most dog bites occur during initially non-aggressive interactions with the dog (e.g., during petting, playing), in our study we discerned a wide variety of contexts, including those in which the person did not intend to interact with the dog. Most victims reported unprovoked bites during fast movements near the dog, while coming into close proximity, and during incidents without a reason. These incidents more likely occurred in public than private places and were associated with purebred dogs with a history of aggression.

Keywords

dog – human-animal interaction – aggression – bites – contexts

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Introduction

Dogs can exhibit a wide range of behaviors that can be classified as undesirable and could pose a threat to human-dog interactions. Most prevalent behavior problems in dogs involve excessive barking (Chung, Park, Kwon, & Yeon, 2016); jumping on people (Rezac, Koru, & Pospisilova, 2017); and aggression, especially when it is directed towards caretakers or other people (Boyd et al., 2018; Flint, Coe, Serpell, Pearl, & Niel, 2017; McMillan, 2017). Aggression is a behavior that inflicts physical or psychological harm or threatens to do so (Anderson & Bushman, 2002); it can be manifested as threatening behavior (e.g., growling, barking, or baring teeth) or aggressive biting behavior (e.g., snapping or attacking) (Netto & Planta, 1997). The motivation for aggression is not always known, and several underlying mechanisms (typically based on fear, territoriality, possessiveness, predation, pain, intermale conflict, and protectiveness) are assumed to influence aggressive reactions (Blackshaw, 1991; Borchelt, 1983).

The aggressive biting behavior presents a public health problem, since many people bitten by a dog must seek professional medical help (Horisberger, Stärk, Rüfenacht, Pillonel, & Steiger, 2004; Rosado, Garcia-Belenguer, Leon, & Palacio, 2009). Many dog bites go unreported (e.g., Oxley et al., 2018), and medical attention may be sought from nonprofessionals. Some bites can lead to hospitalization (Súilleabháin, 2015), transmission of infectious diseases such as rabies (Fooks et al., 2017), plastic and reconstructive surgeries (Cameron, Al-Himdani, & Oliver, 2017) or even death (Mora, Fonseca, Navarro, Castaño, & Lucena, 2018). Additionally, aggressive behavior is a common reason for dogs being relinquished to animal shelters, seized by local authorities, abandoned, or euthanized (Lambert, Coe, Niel, Dewey, & Sargeant, 2015), turning the aftermath of dog aggression into a nonhuman animal welfare issue.

There is a large body of evidence on post-bite responsibilities for victims, mainly reporting the location and the severity of the bite wounds (Oxley, Christley, & Westgarth, 2018; Rosado et al., 2009; Sarcey, Ricard, Thelot, & Beata, 2017), along with the basic characteristics of the dogs involved. The dogs are mainly adult males who are known to the victim (Oxley et al., 2018; Rosado et al., 2009; Sarcey et al., 2017). The reported breeds range from smaller (e.g., Shih Tzus: Messam, Kass, Chomel, & Hart, 2012) to bigger breeds (e.g., German Shepherds: Oxley et al., 2018); however, the victims involved in the biting incidents can potentially misidentify the breed of the dog, resulting in misleading breed statistics.

Regarding the biting incident itself, current data suggest that the majority of dog bites occur on private properties (Cornelissen & Hopster, 2010; Oxley et al., 2018) during a contact activity with the dog, such as while stroking and playing (Cornelissen & Hopster, 2010; Horisberger et al., 2004; Oxley et al., 2018) or manipulating the dog in an aversive way (Rosado et al., 2009). However, most of these studies lack a thorough description of the situation before and during the biting incident, as well as a precise description of the location where the bite occurred. Exceptions include Oxley et al. (2018), who included a small sample of biting incident descriptions that were limited only to contact activities with the dog; Owczarczak-Garstecka, Watkins, Christley, and Westgarth (2018), and Owczarczak-Garstecka, Watkins, Christley, Yang, and Westgarth (2018), who studied YouTube videos of dog bites; and Westgarth and Watkins (2015), who interviewed a sample of 8 female biting victims. There are even fewer data about the interaction at the time, including details such as the restriction of movement of the dogs and their additional characteristics, including their origin, prior socialization, behavioral training, and housing conditions.

Dog bites represent a global problem. It is therefore important to identify potential factors related to biting incidents that could provide a new perspective on this problem and help manage and reduce the undesirable and dangerous behavior in dogs. In this study, we gathered information about self-reported dog-biting incidents in Slovenia, focusing on dog- and situation-related characteristics regarding the incident to identify the main risk factors for the aggressive biting behavior. Based on the variety of different descriptions of dog bites during interactions or attempted interactions presented by Oxley et al. (2018), as well as the lack of detailed descriptions of the circumstances of the interactions – especially before the incidents – our main goal was to explore factors responsible for the dog-human aggression resulting in bites, with the focus on the contextual aspects of the biting incidents. We hypothesized that further understanding of the context of aggressive dog-biting behavior will lead us towards a broader picture, showing that dog bites occur in a larger number of circumstances than previously reported.

Materials & Methods

Data Collection

The questionnaire used in this study comprised a combination of previously used questions from related studies (Messam et al., 2012; Oxley et al., 2018; Rosado et al., 2009), with additional questions regarding restriction of movement, housing conditions, and the intensity of the bite. An open-ended question about the context in which the bite occurred was also included.

A pilot study with 10 participants was conducted prior to the final study to test for question ambiguity. Responders' feedback was used to create the final questionnaire that contained 6 open-ended questions and 23 close-ended questions, divided into four sections. The first part was about the victim's gender, current age, age when the bite happened, and relationship to the dog (e.g., guardian, neighbor). The second part touched on the dog's age, sex, size, breed, ownership, housing (e.g., living indoors, outdoors, chained), medical problems, origin (e.g., breeder, shelter), neutering status, past behavior training, socialization as a puppy, and past aggression (toward people and dogs). The third part asked about the incident, including the dog's intention (intentional bite or an accident), the approach, presence of others, restriction of the dog's movement (e.g., unrestricted, on a lead, chained), area (urban/rural), precise location, victim and dog's prior behaviors, situation and interaction before the bite, and intensity of the bite (e.g., one or more bites). The last question was about the post-bite implications for the dog.

The questionnaire was composed online using OneClick survey software (www.1ka.si) and was available online from December 2017 until February 2018. The link to the questionnaire, shared through Facebook and various faculty electronic mailing lists, included a short presentation of the aims of the study, inclusion criteria stating that respondents had to be 18 years of age or older and previously bitten by a dog, and consent for usage of the provided (anonymous) information for research purposes. No specific ethical approval was required, and no personal details were gathered. The questionnaire is available upon request.

Statistical Analysis

Qualitative data from open-ended questions about the breed of the attacking dog, location of the bite, circumstances before the bite, and interaction with the dog before the bite were subjected to content analysis, answer by answer. Qualitative text analysis software (QDA Miner Lite, Provalis Research), which provided visualization, fast searches, and the ability to add comments, assisted researchers in grouping the categories. Data from close-ended questions were automatically converted into numerical form by the survey software. Statistical analyses were performed using IBM SPSS Statistics for Windows, version 22. Continuous variables (e.g., caretaker's age) were presented as means and standard deviations, and categorical variables (other data) were presented as frequencies.

The categorical variables that were obtained with open-ended questions were grouped into two classes. Interaction with the dog was grouped as present or not present prior to the bite, location was grouped as private or public, and breed was grouped as purebred or crossbred. Associations between different categorical variables were assessed using nondirectional chi-square tests with calculated odds ratios (*OR*) and 95% confidence intervals (*CI*). A binary logistic regression model was used to estimate potential risk factors (breed, sex, age, size, history of aggression, socialization and behavioral training, relationship with the victim, neuter status, location, and area) for bites with or without prior interaction. Variables for the final models were selected using backward elimination until all the main effects were significant. Values of responses "unknown" were considered missing data. Statistical significance was accepted if $p < 0.05$.

Results

A total of 460 responses were received, out of which 60 were excluded for various reasons (e.g., respondent was under 18 or answered less than 50% of the questions), leaving 400 self-reported victims of dog bites. Data on respondent demographics are presented in Table 1. Respondents were primarily female ($n = 310$, 77.5%), between 18 and 86 years old (mean ± *SD*; 32.7 ± 12.5), and most commonly bitten when they were younger than 19 years old ($n = 271$, 67.8%). Children were less likely to be bitten by a known dog than adults were, $\chi^2(1, N = 400) = 6.1$, $p = .014$, *OR* = 0.4, 95% CI [0.3, 0.9]. Respondents were more likely to be bitten by a dog with a history of aggression than a dog with no history

TABLE 1 Respondent demographics

Characteristics	Categories	*n*	%
Sex	Female	310	77.5
	Male	90	22.5
	Total	400	100
Age during bite	Child (0–9 years)	97	24.3
	Teenager (10–19 years)	174	43.5
	Adult (20–59 years)	127	31.8
	Older adult (> 10 years)	2	0.5
	Total	400	100
Relationship to dog	Caretaker	33	8.3
	Cohabitant	21	5.3
	Family member's or friend's dog	98	24.5
	Neighbor's dog	72	18
	Acquaintance (e.g., from walks)	49	12.3
	No prior relationship	117	29.3
	Other	10	2.5
	Total	400	100

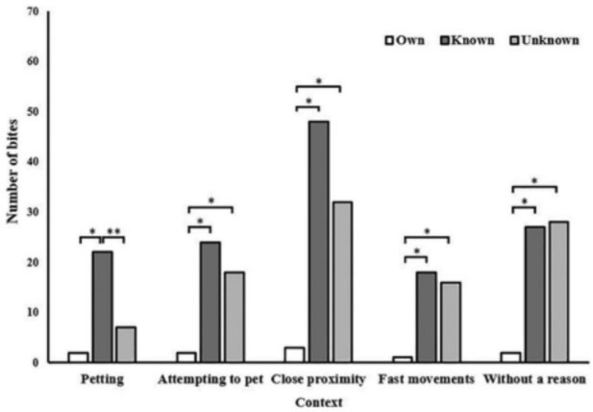

FIGURE 1 Involvement of dogs that were owned by, or cohabitated with, the victim (own); dogs that were known or only acquainted (known) with the victim; and completely unknown dogs (unknown) in different biting contexts (χ^2, *p < 0.001; **p = 0.005).

of aggression, $\chi^2(1, N = 400) = 6.4$, $p = .011$, OR = 1.8, 95% CI [1.1, 2.7], and more likely to have been on private property than public property, $\chi^2(1, N = 400) = 3.9$, $p = .049$, OR = 1.5, 95% CI [1.0, 2.3].

The majority of the respondents knew the attacking dog prior to the bite, most commonly stating that the dog belonged to their family members or friends (n = 98, 24.5%) and neighbors (n = 72, 18%), while 117 respondents (29.3%) did not have any prior relationship with the dog. Figure 1 shows the prevalence of dogs involved in the five most common biting contexts. In all contexts, the number of bite incidents significantly differed the regarding dog-human relationship ($\chi^2 = 20.9$, $p < .001$ for petting; $\chi^2 = 17.6$, $p < .001$ for attempting to pet; $\chi^2 = 37.6$, $p < .001$ for being in a close proximity; $\chi = 22.8$, $p < .001$ for biting incidents without a reason; and $\chi^2 = 14.8$, $p = .001$ for fast movements). Specifically, there were fewer bite incidents by owned compared to known and unknown dogs for all these contexts except petting, for which known dogs were represented more in bite incidents than unknown dogs.

Dog Characteristics

Dogs involved in the biting incidents were primarily male (n = 270, 67.5%), between 2 and 10 years old (n = 279, 69.8%), large in size (n = 190, 47.5%), and from a breeder (n = 77, 19.3%). Almost all were owned (n = 386, 96.5%), with few incidents involving stray dogs (n = 8, 2%) or dogs of an unknown status (n = 6, 1.5%). More than half of the dogs (n = 217, 54.3%) were reported as healthy at the time of the incident, and the neuter status of the dogs was mainly unknown (n = 194, 48.5%). The largest proportion of the dogs (n = 180, 45%) lived outdoors, and of those, 73 (18.3%) were chained. Further data on the basic characteristics are presented in Table 2.

For 226 dogs (56.5%), their behavioral history was unknown; 124 dogs (31%) were socialized as puppies and 50 (12.5%) were not. A small number of dogs (n = 45; 11.3%) had previously attended behavioral training; 175 (43.8%) had no previous behavioral training; and for 180 (45%), their behavioral training was unknown. Half (n = 199, 49.8%) of the respondents were not familiar with the

TABLE 2 Characteristic of the dogs involved in the biting incidents

Dog characteristics	Categories	n	%
Age	Puppy (< 6 months)	6	1.5
	Young dog (6 months–2 years)	66	16.5
	Adult dog (2–10 years)	279	69.8
	Old dog (> 10 years)	26	6.5
	Unknown	23	6.5
	Total	400	100
Sex	Female	77	19.3
	Male	270	67.5
	Unknown	53	13.3
	Total	400	100
Size	Toy	28	7
	Small	97	24.3
	Medium	69	17.3
	Large	190	47.5
	Giant	16	4
	Total	400	100
Origin	Breeder	77	19.3
	Shelter, Rescue Center	12	3
	Friend, Relative	54	13.5
	Home-bred	57	14.2
	Stray	10	2.5
	Other	5	1.3
	Unknown	185	46.3
	Total	400	100
Medical status	No medical problems	217	54.3
	Various injuries	5	1.3
	Sight or hearing problems	13	3.3
	Other medical problems	20	5

TABLE 2 Characteristic of the dogs involved in the biting incidents (*cont.*)

Dog characteristics	Categories	*n*	%
	Unknown	145	36.3
	Total	400	100
Neutering status	Neutered	55	13.8
	Unneutered	151	37.8
	Unknown	194	48.5
	Total	400	100
Housing conditions	Indoors	90	22.5
	Outdoors	180	45
	Indoors and outdoors	62	15.5
	Unknown	68	17
	Total	400	100

dog's history of aggression, and 64 (16%) respondents stated that the dog had no history of aggression. Out of the dogs with a history of aggression (n = 137, 34.3%), 40 (10%) were aggressive only towards other people, 20 (5%) only towards other dogs, and 77 (19.3%) towards both other people and other dogs. Dogs with a history of biting were more likely to be involved in biting incidents occurring without a reason, $\chi^2(1, N = 400) = 5.1$, $p = .024$, $OR = 2.8$, 95% CI [1.1, 7.2], and less likely to bite on private property, $\chi^2(1, N = 400) = 5.8$, $p = .016$, $OR = 0.5$, 95% CI [0.2, 0.9].

Of the respondents, 85 victims (21.3%) were not familiar with the breed of the dog that attacked them. A total of 88 (22.0%) victims stated that the dog was crossbred, and of those dogs, 20 (5%) had breeds that were known (e.g., mix between Rottweiler and German Shepherd). There were 59 different recognized breeds, with German Shepherd (n = 80, 20% of all dogs) being the most common, followed by Golden Retriever (n = 14, 3.5%), Chihuahua (n = 13, 3.3%), and Maltese (n = 12, 3.0%).

Information about the Biting Incidents

At the time of the biting incident, the majority of the respondents (n = 253, 63.2%) were not alone. Half of them (n = 201, 50.3%) were with another person, 18 (4.6%) were with their dog, and 34 (8.7%) were accompanied by another person and another dog. The rest (n = 134, 36.8%) were alone during the incident. The caretaker of the attacking dog was present in 214 cases (55%), and the biting dog was completely alone in 170 cases (43.7%). For 13 incidents, there were missing data.

The majority of the dogs (n = 271, 69.7%) were unrestrained before the bite, 44 dogs (11.3%) were on a lead, 38 dogs (9.8%) were chained, and 24 dogs (6.2%) were inside a fence. For 23 incidents, there were missing data. The dog approached the victim in 143 cases (36.8%), the victim approached the dog in 141 cases (36.2%), and they approached each other in 78 cases (20.1%). For 38 incidents, there were missing data.

Most victims (n = 255, 65.6%) interpreted the bite as intentional and themselves as relaxed (n = 162, 41.6%), excited (n = 98, 25.2%), or happy (n = 36, 9.3%) prior to the biting incident. They described the behavior of the attacking dog before the bite as tense (n = 68, 17.5%), excited (n = 61, 15.7%), or aggressive (n = 59, 15.2%). A few respondents did not remember the behavior of the dog (n = 80, 20.6%).

The circumstances before the biting incident happened are presented in Table 3. No prior interaction with the dog was most often mentioned (n = 210, 56.3%), followed by a direct interaction with the dog (n = 141, 37.8%). When the biting incident happened, 83 victims came into close proximity of the dog (n = 83, 22.3%), and some of them (n = 62, 16.6%) interpreted the bites as having happened without a reason. Of those who (intentionally) did interact with the dog during the biting incident, 31 were petting the dog (8.3%) and 44 were attempting to pet the dog (11.8%). Further data on the interaction during the bite are presented in Table 3. During incidents with prior interaction, bites were 3.6 times more likely to occur in private than in public spaces.

During incidents with prior interaction, dogs with a history of aggression were 2.5 times more likely to bite compared to dogs without a history of the behavior, and unneutered dogs were more likely to bite compared to neutered dogs (Table 4). During incidents without prior interaction, bites were 4.5 times more likely to occur in public spaces than in private. Purebred dogs were 3 times more likely to be involved in bites compared to mixed-breed dogs. Dogs with no history of aggression were less likely to bite compared to dogs with a history of aggression (Table 5).

Regarding the intensity, in most cases, one bite happened (n = 354, 91.0%) during the incident, and of those, in 68 cases (17.5%), the dog had to be pulled away. Several bites occurred in 26 cases (6.7%), and of those, 12 dogs (3.1%) had to be pulled away. For 9 incidents, the answer regarding the intensity was "Other," and for 11 incidents, there were missing data.

Location of the Biting Incidents

Most of the dog-biting incidents (258, 66.3%) occurred in a low-populated area (e.g., countryside, village), and 131 incidents (32.7%) occurred in a high-populated area (e.g., city, town). There were missing data for 11 incidents. Table 6 summarizes the precise locations of the incidents, described by the

TABLE 3 Circumstances before and during the dog bite

Time	Interaction	Circumstances	*n*	%
Before	Yes	Interacting with dog	88	23.6
		Attempting to interact with dog	53	14.2
	No	Walking past or toward dog	98	26.3
		Interacting with another person	19	5.1
		Standing beside dog	10	2.7
		Entering inside area (e.g., house, room)	12	3.2
		Entering outside area (e.g., garden, courtyard)	10	2.7
		Running, cycling, roller-skating	30	8
		Dog-dog aggression	26	7
		Exiting or entering car	5	1.3
	Other		22	5.9
	Total		373	100
	Missing		27	
During	Yes	Petting dog	31	8.3
		Attempting to pet dog	44	11.8
		Other tactile interactions (e.g., handling, restraining dog)	27	7.2
		Playing with dog	20	5.4
		Grooming dog	6	1.6
		Medical examination or procedure	5	1.3
		Interacting with an eating dog	18	4.8
		Interacting with a sleeping or resting dog	10	2.7
		Attempting to separate fighting dogs	26	7
	No	Without a reason	62	16.6
		Fast movements near dog (e.g., running, cycling)	35	9.4
		Being in close proximity (e.g., walked past the dog)	83	22.3
	Other		6	1.6
	Total		373	100
	Missing		27	

TABLE 4 Significant predictors for dog bites with prior interaction

Predictor	Wald Chi-Square	*df*	*p*-value	OR	95% CI for OR	
					Lower	Upper
Public space	6.026	1	0.014	0.362	0.161	0.815
Neutered dog	5.128	1	0.024	0.362	0.152	0.873
History of aggression	4.954	1	0.026	2.519	1.117	5.683

TABLE 5 Significant predictors for dog bites without prior interaction

Predictor	Wald Chi-Square	*df*	*p*-value	OR	95% CI for OR	
					Lower	Upper
Public space	18.190	1	0.000	4.495	2.253	8.969
Crossbred dog	11.401	1	0.001	3.033	1.255	7.328
No history of aggression	7.004	1	0.008	0.391	0.195	0.784

victims. The most common answers were that it happened on the road, street, or square (n = 113, 29.0%); inside or outside someone else's property (n = 69, 17.4%); or it was unclear whether it was inside or outside their own or someone else's property (n = 84, 21.6%). Regarding incidents on private property, 62 bites (15.9%) happened indoors, and 143 bites (36.8%) happened outdoors. Bites on private property were more likely to occur during a direct interaction with the dog, $\chi^2(1, N = 400) = 38.3$, $p = .001$, OR = 3.9, 95% CI [2.5, 6.0] and involve a dog known to the victim, $\chi^2(1, N = 400) = 45.0$, $p = .001$, OR = 4.7, 95% CI [3.0, 7.6].

Implications for the Dog after the Biting Incident

For the majority of the dogs (n = 246, 66.0%), there were no post-bite implications, or the respondent had no knowledge about this (n = 41, 11.0%). The most common implication was separation or verbal punishment (n = 28, 7.5%), and 23 dogs (6.2%) were euthanized.

Other implications (a control order was implemented; dog was rehomed, seized by police, or neutered) were cited by 9.3% of the respondents.

TABLE 6 The location and the number of biting incidents

Location	*n*	%
Inside own property	17	4.4
Outside own property	16	4.1
Inside someone else's property	21	5.5
Outside someone else's property	48	12.3
Unclear if inside own or someone else's property	20	5.1
Unclear if outside own or someone else's property	64	16.5
Inside an apartment building	4	1.0
Outside an apartment building	6	1.5
Road, street, square	113	29.0
Park	16	4.1
Car park	5	1.3
Walking trail	5	1.3
Field, woods	15	3.9
Country lane	9	2.3
Dog-related places (e.g., dog training, vet, dog show, kennel)	9	2.3
Bar, restaurant	5	1.3
Other (e.g., beach, vineyard)	16	4.1
Total	389	100
Missing	11	

Discussion

We gathered information about human-directed aggression involving dog bites from 400 self-reported victims from Slovenia. Self-reported data were collected instead of hospital or clinical data because many dog bite victims do not seek medical help (Oxley et al., 2018; Westgarth, Brooke, & Christley, 2018). Using open-ended questions in a questionnaire, responders had the opportunity to describe the contexts and locations of biting incidents. The results showed that the contexts of the dog bites included bites during fast movements around the dog, while coming into close proximity to the dog, and during incidents without a reason. In these incidents, when bites occurred without the victim intentionally interacting with the dog, purebred dogs with a history of aggression were involved. We also identified roads and streets as frequent public locations of dog-biting incidents, and areas around the house (e.g., yards, driveways) as frequent private locations, like Oxley et al. (2018).

The literature has shown that men are more likely to get bitten by a dog than are women (e.g., Súilleabháin, 2015; Westgarth et al., 2018). We observed no sex effect in our study; female respondents may be overrepresented, as men are less likely to respond to Web surveys (Sax, Gilmartin, & Bryant, 2003). Regarding age, there is a great body of research implying that children (e.g., Touré, Angoulangouli, & Méningaud, 2015) and teenagers (Bregman & Slavinski, 2012) have a higher likelihood of being bitten by a dog, with injury rates decreasing with increasing age; the fewest bites were reported in older adults (Quirk, 2012). Our results are in line with these studies, with children and teenagers between 10 and 19 years old being the age groups at most risk. Their frequent involvement in biting incidents may be explained by improper supervision around dogs (Shields, McDonald, Stepnitz, McKenzie, & Gielen, 2012), as most of the dogs in our study had a history of being aggressive and/or were privately owned.

Other possible explanations could be young people's fast movements and loud noises, physical expression of affection towards the dog, intense curiosity, and lack of knowledge of dogs' social behavior and signals of distress (Love & Overall, 2001). We also found fewer reported bites towards the caretakers of the dogs and complete strangers than those acquainted with the dogs (i.e., family members, neighbors, and other acquaintances), making the latter relationship group at most risk. That the least number of bite incidents in different contexts (i.e., attempting to pet, being in close proximity, and following fast movements) involved owned dogs further supports this suggestion.

Consistent with previous findings (Oxley et al., 2018; Sarcey et al., 2017), dogs causing bite injuries were primarily large, adult males who originated from a breeder, friend, or relative. They were also healthy during the biting incidents, as we excluded pain- and disease-induced aggression as a frequent cause for biting (Camps, Amat, Mariotti, Le Brech, & Manteca, 2012). The majority of the dogs were unneutered, which is in agreement with some studies (Patronek, Sacks, Delise, Cleary, & Marder, 2013; Shuler, DeBess, Lapidus, & Hedberg, 2008) but not others (Flint et al., 2017; Oxley et al., 2018). Furthermore, our results support Wormald, Lawrence, Carter, and Fisher (2016), who showed that being socialized with other dogs during the first 8 weeks of age does not reduce aggressiveness. However, it may be important for the dogs to attend behavior training (Owczarczak-Garstecka et al., 2018), even though, in our study, not attending training was not identified as a risk factor.

Considering the housing conditions of dogs expressing aggressive biting behaviors, living exclusively outdoors and being chained seemed to be the main environmental conditions. This supports the reports of Gershman, Sacks, and Wright (1994), who found that dogs chained in the yard is a major risk factor for biting in the USA. Our results also showed that most dogs involved in the biting incidents were known to have a history of aggressive behavior towards people and other dogs. This implies that these dogs may exhibit aggression in the future and so present a serious threat because, as seen in this study, they are frequently involved in bites without prior interaction. In contrast to our findings, Sarcey et al. (2017) reported frequent bites from dogs that had never previously bitten, while Oxley et al. (2018) found no effect of the history of biting. This inconsistency in the results makes us believe that it is probable that any dog can exhibit aggressive behavior as a response to threats in specific contexts (Bradshaw, Blackwell, & Casey, 2009), even if the dog has never done so previously (De Keuster, Lamoureux, & Kahn, 2006).

Since a small number of dogs in our study were reported as being crossbred (crossbreeds represent almost half of all registered dogs in Slovenia: Central Dog Register, 2018), being a purebred dog may present a high risk for dog bites. There is substantial variation among breeds and consistency within breeds regarding the severity and prevalence of stranger-, caretaker-, and dog-directed aggression (Duffy, Hsu, & Serpell, 2008). As reported previously (e.g., Oxley et al., 2018; Sarcey et al., 2017), and further supported in our study, German Shepherds are most commonly involved in biting incidents. In our case, they are also the most common purebred in Slovenia; however, they represent 6% of all registered dogs in the country (Central Dog Register, 2018) and therefore, they most likely were not an overrepresented breed in our sample. Despite being known to have low aggressive tendencies (Arata, Takeuchi, Inoue, & Mori, 2014; Duffy et al., 2008), Golden Retrievers were the second most commonly described breed in our study, which may be related to their high heritability (0.77) of human-directed aggression (Liinamo et al., 2007) or to their higher popularity (Central Dog Register, 2018).

Another finding was that, despite larger breeds representing the largest proportion of biting dogs, a considerable number of smaller breeds like Chihuahua and Maltese were mentioned by the victims in our study, as in others (Arata et al., 2014; Duffy et al., 2008). The reason can be found in higher caretaker tolerance of aggressive behavior in smaller dogs, since they may cause less damage than bigger dogs (Guy et al., 2001). This is also why there were no post-bite consequences for the majority of the dogs involved, with only some of them being euthanized. Considering that there were 59 recognized breeds in our study, from various breed groups, biting does not seem to be limited to certain breeds or groups. It seems that dogs of all breeds with various behavioral and personality traits can cause bite injuries (Kaneko, Arata, Takeuchi, & Mori, 2013), and a breed's frequency in the population may be a better predictor of aggression than breed per se.

Most victims in our survey, and others (Cornelissen & Hopster, 2010; Oxley et al., 2018), believed that the bites were not an accident and that the dogs intended to bite them. Not even the presence of other people or dogs appeared to reduce the likelihood of the biting incident, since the majority of our responders/dogs were not alone while it happened. There might have been a lack of appropriate caretaker control or supervision over the dog. This could especially be relevant in dog-child interactions, where we found the most bites, and where according to Arhant, Landenberger, Beetz, and Troxler (2016), caregivers may not always correctly identify when the intervention is needed. Regarding the psychological state before the incident, victims most commonly reported their state as "positive," saying that they were relaxed, happy, and/or excited. Dogs, on the other hand, were described as tense or aggressive, but also excited, which may also illustrate responders' difficulties in identifying dogs' affective states.

The characteristics of biting incidents mentioned in our survey were diverse. Firstly, our study further supports that low-populated and/or rural areas are higher risk geographical locations for dog bites than urban areas, as indicated previously (Babazadeh et al., 2016; Rosado et al., 2009). This may be linked to the caretakers controlling and restraining their dogs more in the urban areas due to heavier traffic, more people, and less open space (Rosado et al., 2009). One half of the victims stated that the bite happened while interacting with the dog, mostly while petting or attempting to pet the dog, or playing with a known dog that belonged to family or a friend. Bites during previous interactions most frequently occurred outside someone else's property. Bending over the dog is frequently part of these kinds of interactions and can potentially cause fear-related aggression (Kuhne, Hößler, & Struwe, 2014).

The other half of our victims described the incident as occurring without prior interaction, resulting mostly in one bite that was unprovoked while they were acting passively in a public space in the vicinity of an unknown or acquaintance's dog's home. Westgarth and Watkins (2015) previously reported four similar occasions of dog bites in which the victim did not previously interact with the dog. The dogs involved in no prior interactions were more often purebred with a history of aggression. Before the incidents, victims were often walking past or toward a dog while making fast movements outside someone else's property or while riding a bike on the street. From the literature we know that getting into close proximity of a dog, particularly if the dog perceives the location as their territory, even without actual threat, can cause territorial aggression (Chávez & Opazo, 2012; Owczarczak-Garstecka et al., 2018), especially when in contact with a person whom they do not live with (Kuhne et al., 2014; Tuber, Henessey, Sanders, & Miller, 1996).

It seems that the victims did not always anticipate the interaction, so they may have had no opportunity to assess the situation and adapt their behavior accordingly. Finding that circumstances for biting incidents involving no prior interaction were as important as the ones with prior contact, we suggest a more complex context-based factor than previously suggested (Gautret et al., 2013; Oxley et al., 2018; Sarcey et al., 2017). For bites in contexts without prior interaction, education about preventive methods, such as knowledge about dog social signaling or body language is not applicable. Therefore, we believe that the education of handlers regarding the proper controlling and supervision of dogs at all times and knowledge about potential risk factors for biting are the best prevention for these kinds of bites.

One limitation of our study is that our results are based on a Web-based convenience sample that likely does not represent the general population (Fricker, 2008). The data were also not as thorough as we hoped, since many respondents did not have sufficient knowledge (e.g., behavioral history, medical status) of the dog that attacked them. The reason for this is due in part to the retrospective collection of the data that depends on victims' recollections of an event that happened a long time ago. Additionally, the terms used in the questionnaire, such as "aggression" and "socialization," were not further explained; thus, the respondents' understanding of these terms cannot be certain.

All the respondents were in Slovenia where there is currently no scientific data about the prevalence of dog bites; however the population of dogs appears to be increasing ("Number of dogs in Slovenia 2010–2017," 2019). The respondents were also predominantly female, so the results reflect a limited geographical area and sex. We believe that every geographical region has unique characteristics (e.g., housing of the dogs, distribution of rural and urban areas) that can influence results. This assumption gives room for further research and the opportunity to explore the potential differences in contextual aspects of dog bites in various geographical regions.

Conclusion

The basic profiles of the biting dogs and victims were consistent with those previously found, mainly involving children bitten by an adult; a male; or a large, previously known dog. The in-depth contextual aspects of dog bites were described in this study. Even though many bites occurred with dogs that the victims had interacted with (e.g., while petting or playing), the most important finding was the identification of contexts in which the victims were not seeking direct interaction with a dog. They happened mainly during fast movements around the dog or while being in close proximity to the dog without seeking contact, and they were reported as happening without a reason. Dogs involved in these incidents mainly had a history of aggression and were purebred, with German Shepherds being most commonly represented.

Regarding the location of the incidents, we identified the outside area of private properties, such as gardens and driveways, as a risk location, as well as streets and roads. In the light of these findings, we believe that bites without prior interaction need further research, as they are more difficult to prevent, since the assessment of dog behavior or warning signs and the appropriate adjustment of behavior are challenging when the interaction with the dog is not expected and other preventive methods, such as education of the handlers, are needed.

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2.1.2 Dogs' sociability, owners' neuroticism and attachment style to pets as predictors of dog aggression

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A dog's aggressive behavior is influenced by external and internal factors, including its psychological profile. In this study, dogs' and owners' personalities and the owners' attachment style to their dogs were identified and associated with owner-reported dog aggression towards humans and animals. Forty Slovenian owners participated with their dogs, of different breeds and aggression history, sorted into three groups (non-aggressive dogs, dogs aggressive towards humans, and dogs aggressive towards animals). The owners filled out three separate questionnaires that assessed dog aggression history towards different targets, owner's personality and degree of insecure attachment styles to dogs; namely anxious and avoidant attachment. Dog personality was characterized using a standardized dog mentality assessment test, during which the dog was exposed to nine tasks, performed outside, and dogs were scored based on behaviors they exhibited. The results indicated that dogs which were aggressive towards humans were less sociable than non-aggressive dogs and this was associated with the higher neuroticism scores of their owners. We also found that dogs which were aggressive towards strangers had owners with lower scores for anxious attachment and that dogs which were aggressive towards owners had owners with higher scores for avoidant attachment. These results imply that the psychological profiles of both a dog and its owner influence dog aggression towards humans.

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Dogs' Sociability, Owners' Neuroticism and Attachment Style to Pets as Predictors of Dog Aggression

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Simple Summary: It is widely known that psychological characteristics, for example personality traits, can facilitate the occurrence of aggressive behavior. Using the combination of two research methods—questionnaires and behavioral testing—we investigated the associations between a dog's personality and its aggression towards humans and animals. Due to the close relationship and co-habitation of dogs and humans, we also looked at how the owner's personality and the dog–human emotional bond, known as attachment style, play a role in dog aggression. Our results indicated that dogs which were aggressive towards humans were less sociable, and had owners who were less emotionally stable, more distant, and less clingy and controlling, compared to non-aggressive dogs. These results emphasize the importance of owner attachment to a dog for dog behavior, and may serve as a foundation for future research on psychosocial factors influencing dog aggression.

Abstract: A dog's aggressive behavior is influenced by external and internal factors, including its psychological profile. In this study, dogs' and owners' personalities and the owners' attachment style to their dogs were identified and associated with owner-reported dog aggression towards humans and animals. Forty Slovenian owners participated with their dogs, of different breeds and aggression history, sorted into three groups (non-aggressive dogs, dogs aggressive towards humans, and dogs aggressive towards animals). The owners filled out three separate questionnaires that assessed dog aggression history towards different targets, owner's personality and degree of insecure attachment styles to dogs; namely anxious and avoidant attachment. Dog personality was characterized using a standardized dog mentality assessment test, during which the dog was exposed to nine tasks, performed outside, and dogs were scored based on behaviors they exhibited. The results indicated that dogs which were aggressive towards humans were less sociable than non-aggressive dogs and this was associated with the higher neuroticism scores of their owners. We also found that dogs which were aggressive towards strangers had owners with lower scores for anxious attachment and that dogs which were aggressive towards owners had owners with higher scores for avoidant attachment. These results imply that the psychological profiles of both a dog and its owner influence dog aggression towards humans.

Keywords: dogs; dog owners; aggression; personality traits; attachment

1. Introduction

Historically, the primary role of dogs was in guarding, herding and hunting, but their high socio-cognitive abilities and capability to form a close relationship with humans [1,2] have made them an integral part of human society. Nowadays, whilst many still play an important role as working dogs [3–6], the most common reason for owning a dog is companionship [7]. Despite the fact that the role of pet dogs in Western cultures has been elevated to the status of a family member [8], there are several factors that can negatively affect the quality of the dog–human bond, with aggression being the most serious [9,10]. Aggressive behavior of dogs is expressed as aggressive biting, by snapping or attacking, and aggressive threatening, by growling, barking and baring their teeth [11]. It can be classified by motivational basis (territorial-, fear-, possessiveness-related, etc.) or targeted basis (stranger-, owner-, dog-directed etc.) [12], and can be influenced by a variety of factors. These include environment, maternal and sibling interactions, experience in the form of socialization and learning, as well as different biological [13] and psychological correlates, including an individual's personality traits.

Animal personality is defined as a consistency of inter-individual behavioral traits through time and across contexts [14,15] and can be characterized using standardized tests [16]. In dogs, there are two main methods for the assessment of personality: questionnaires and behavioral tests [17]. Both methods have advantages and disadvantages. For instance, gaining information from dog owners using questionnaires is less time consuming, allows for a larger and a more diverse sample, and involves a person who lives with the dog and knows more about the dog's everyday behavior [18]. On the other hand, it means that behavior is often assessed by people that do not have sufficient knowledge of animal behavior. This makes behavioral observations and interpretations made by professionals in the field more objective, precise and free of owner bias [19]. One of the most widely used behavioral tests is the standardized Dog Mentality Assessment (DMA) that was developed by the Swedish Working Dog Association and measures a dog's reaction to different stimuli [20]. The assessments using the DMA revealed five personality traits, labelled as playfulness, curiosity/fearlessness, chase-proneness, sociability and aggressiveness, as well as one broader dimension named shyness/boldness, that is generalized for the dog as a species [20]. Using questionnaire data, personality traits were found to be associated with potential aggressive behavior. For example, more fearful dogs were associated with dog-directed aggression and fear-related aggression [21,22], while lower levels of sociability were related to higher levels of stranger-directed and child-directed aggression [23].

Aside from the dog's personality traits, its owner's psychological characteristics may lead to pronounced dog aggression, due to their co-habitation and close relationship. For instance, owners with lower ratings for the personality traits of agreeableness, emotional stability, extraversion and conscientiousness often have dogs showing higher levels of aggression towards owners and a fear of strangers [24]. Additionally, the owner's personality traits have also been significantly correlated with those of their dog, using the Big Five factor taxonomy [25]. The reason behind this may be the shared social environment and activities, resulting in a higher degree of emotional contagion, or a selection process, where the owners select a dog that matches their personality and lifestyle, as seen in romantic partner and friend selection in humans [26].

Another factor that may influence a dog's aggressive behavior is the cognitive-emotional bond, known as attachment. The concept of attachment was initially developed to describe the affectional bond of children to their caregivers and later between adults [27]. The use of the term was further extended into contexts involving humans and objects, places and non-human animals [28,29]. It was previously suggested that humans can form an attachment to their dogs [30] and that this relationship is comparable to the one between a parent and a child [31], as human behavior towards dogs and children tends to be similar [32,33]. The attachment between two individuals can be secure, defined by comfort with intimacy and trust, or insecure. Two examples of insecure attachment are anxious attachment, characterized by clingy, controlling behavior, and avoidant attachment, defined by avoidance of intimacy [34]. A dog–human bond is more influenced by human factors than canine factors [35]; therefore the owner's attachment style may have an impact on the dog's behavior. For example, it has been reported that dogs of owners with lower or higher adult attachment scores (in attachment anxiety, confidence and avoidant attachment subscales) may develop different behavioral strategies during challenging situations [36]. Additionally, the adult attachment styles have also been associated with behavioral problems in dogs; more precisely, owners scoring high on avoidant attachment were reported to have dogs with increased occurrence of separation-related disorder [37].

Here, we investigated the associations between owner- and dog-related psychosocial factors and dog aggression towards different targets, using a combination of two research methods: behavioral testing, that has not previously been used while studying dog aggression from a psychosocial perspective, and questionnaire-based evaluations. For behavioral testing, we used the personality taxonomy of Svartberg and Forkman [20]. Based on the previous studies using only questionnaires, we predicted that dogs with owner-reported aggressive behavior would have higher trait scores for aggressiveness and chase-proneness, and lower trait scores for playfulness, curiosity/fearlessness and sociability. Secondly, we hypothesized that aggressive dogs would be associated with owners having lower scores for agreeableness, extraversion and conscientiousness, but higher neuroticism, and higher owner–dog anxious and avoidant attachment scores than non-aggressive dogs.

2. Materials and Methods

2.1. Participants

Forty dog–owner dyads participated in the study. To include a sample of dogs with diverse behavioral backgrounds, and to compare dogs with and without behavior problems, owners were asked to report their dogs' behavioral history before participation in the study. Once the data were collected, dogs were placed into one of the following categories: dogs with no history of aggression (n =14), dogs with a history of aggression towards humans (n = 13), and dogs with a history of aggression towards dogs and other animals (n = 13). Dogs were of both sexes (16 females; 24 males) and were all older than one year (mean age ± SD, 4.1 ± 2.8 years). There were 17 mongrels and the rest were one of 12 breeds: Pekingese, Tibetan Terrier, Karst Shepherd, Border Collie, Australian Shepherd, German Spitz, Entlebucher, Coton de Tulear, Central Asian Shepherd, Shiba Inu, Brittany, Stafford Terrier. None of the dogs had been previously trained for any particular test battery. The owners accompanying the dogs during behavioral testing were primarily female (n = 26, 65%), aged between 19 and 64 years (mean age ± SD, 33.8 ± 12.7 years) and were the dogs' primary attachment figure (mean years ± SD of cohabitation, 3.9 ± 2.9).

2.2. Protocol

The dog owners were contacted through social media, faculty mailing lists and canine clubs. Those willing to participate received an online generated survey (OneClick survey software© 200–2018 University of Ljubljana, Faculty of Social Sciences, Centre for Social Informatics; www.1ka.si) containing demographic questions, a Canine Behavioral Assessment and a Research Questionnaire (C-BARQ) [18], a Big Five Inventory questionnaire (BFI-10) [38] and an Experiences in Close Relationship—Revised questionnaire (ECR-R) [34]. The owners and their dogs afterwards participated in an adapted DMA test [20] that was performed in a secured open field.

2.3. Assessment of Dogs' Aggressive Behaviour

Further information on the dogs' behavioral history was obtained using the C-BARQ questionnaire for owners [18]. The full questionnaire consists of 68 items, divided into 11 categories, but in this study only aggression related factors (9 items for stranger-directed aggression, 8 items for owner-directed aggression, 3 items for dog-directed aggression and 4 items for chasing) were used. The owners were asked to grade their dogs' typical behavior in a described situation on a 5-point rating scale. The category on chasing behavior was scored on a 5-point frequency scale (0 = never, 1 = seldom, 2 = sometimes, 3 = usually, and 4 = always). For categories regarding owner-, stranger- and dog-directed aggression, a 5-point qualitative scale was used (0 = no signs of the behavior, 1 to 3 = mild to moderate signs of the behavior, and 4 = severe signs of the behavior). As suggested by Hsu and Serpell [18], a brief description of mild, moderate and severe signs of aggression was included in the questionnaire before every question, to help the responder with the grading of their dog's behavior. The mean value of all answers within each category presented the final score of the category, with the higher score representing a more severe expression of behavior.

2.4. Personality Assessment of Dogs

The DMA behavior test was used to determine the dogs' personality traits. The behavioral test consisted of nine subtests that were performed outside in a specifically set test area built in advance (Figure 1). Originally there were 10 subtests, but we excluded the last subtest called Gunshot, because shooting a gun was prohibited at the test location. In addition to the owner that accompanied the dog during the testing, three other persons were present—a test leader, an observer and an assistant. The test leader instructed the owner on how to act before and during each subtest and led the owner through the test. The observer video recorded the dogs' behavioral responses in the test using a Canon XA20 Camcorder. The assistant performed tasks such as pulling up the dummy during the Sudden Appearance subtest. The equipment and its installation was the same in all tests to ensure that the test conditions were similar for the dogs. For safety reasons, dogs were secured with a long (9 m) training leash, even while released from a tighter grip. All the dogs completed the test without any breaks, with a duration of approximately 30 min for each dog.

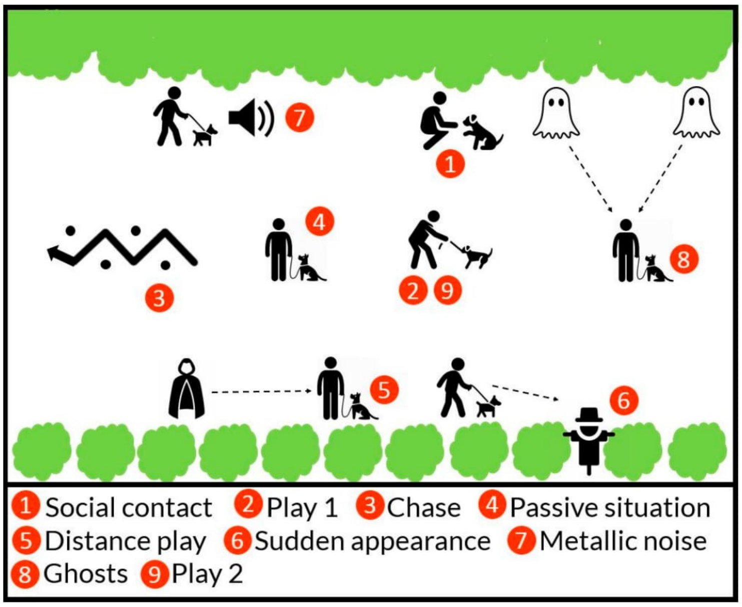

Figure 1. Overview of the outdoor testing area and the position of each subtest; (1) Social contact, (2) Play 1, (3) Chase, (4) Passive situation, (5) Distance play, (6) Sudden appearance, (7) Metallic noise, (8) Ghosts, (9) Play 2.

After the completion of the testing, the dogs' behavioral responses were coded and scored. Score sheets contained subtests, predefined behavioral variables and descriptions of behavior for score 1, 3 and 5 (Table S1). The behavior descriptions for scores 1 and 5 were as described by Svartberg and Forkman [20], while for score 3 we added our own descriptions. A low or high score represented a low or high intensity of the dog's reaction. Based on the scores of behavioral variables, trait scores for each individual dog were calculated (see Svartberg et al., [38]). A second independent person conducted an inter-rater reliability scoring on 30% of the videos. Consistency between coders using an intra-class correlation coefficient (ICC) was excellent: ICC (consistency) >0.9.

2.5. Psychological Assessment of Owners

The abbreviated version of the Big Five Inventory, BFI-10 [39] was used to assess the personality traits of the owners. BFI-10 measured the components of the five factors defined as extraversion, agreeableness, conscientiousness, neuroticism and openness. It consisted of 10 items describing statements about personality, rated on a 5-point scale (1 = disagree strongly, 2 = disagree a little, 3 = neither agree nor disagree, 4 = agree a little, and 5 = agree strongly), with two items for each factor. One item in each factor was reverse scored. The mean value of both answers within each factor represented the final score of the factor 2.6. Owners' Attachment Styles.

A modified ECR-R [34], based on the ECR-R for humans [40], was used to assess owner attachment styles to dogs. Eight items regarding pet-related anxiety and eight items regarding pet-related avoidance were rated on a 7-point scale (1 = strongly disagree to 7 = strongly agree). The mean value of all answers within each variable represented the final score of the attachment style, with a higher score presenting the more severe expression of pet-related anxiety and avoidance.

2.6. Ethical Note

The study was conducted in accordance with the Administration of the Republic of Slovenia for Food Safety, Veterinary Sector and Plant Protection (U3440-14/2019/15). The owners signed a form consenting to data usage and videotaping of the experiment and were given the right to withdraw from the study at any time if the dog showed signs of distress or without giving any reason.

2.7. Statistical Analysis

Data were analyzed using SAS 9.4 (SAS Institute, Cary, NC, USA). Dogs were assigned to three groups, based on their owners' report, (1) non-aggressive group, (2) aggressive towards humans group and (3) aggressive towards animals group. A general linear model (GLM) analysis was used to assess the differences between groups. The residuals followed a normal distribution. For the dogs' personality traits (playfulness, curiosity/fearlessness, chase-proneness, sociability, aggressiveness, shyness/boldness), the fixed effect of the group was tested for differences and the effect of the dogs' age was tested as a covariate. For the owners' personality traits (extraversion, agreeableness, conscientiousness, neuroticism and openness) and the owners' attachment styles (anxious and avoidant), the fixed effects of the group and the owners' gender were tested for differences and the effect of the owners' ages was tested as a covariate. Statistical significance was accepted if $p < 0.05$ and tendency if $p < 0.10$. When a significant effect was found, the LSMEANS and ESTIMATE statements were used to estimate the contrasts between factor levels and to compare their means. When more than two means needed to be compared, a multiple post-hoc Tukey–Kramer test was utilized to find the significant differences. Pearson correlation coefficient calculations were performed using the proc CORR to assess the relationship between the attachment styles and the dogs' personality traits, the owners' personality traits, and the dogs' aggressive behavior, also separately for each of the aggressive classification groups. In the text, only Bonferroni-corrected statistically significant values ($p \leq 0.05$, B: $p \leq 0.01$) and coefficients >0.6 are reported. Four participants did not fill out the ECR-R questionnaire regarding attachment styles and their responses were considered as missing data.

3. Results

The dogs were placed in one of three groups (non-aggressive dogs, dogs aggressive towards humans and dogs aggressive towards animals) based on aggression history reported by their owner. Using behavioral data from C-BARQ, we found that dogs of different groups differed in stranger-directed aggression (F = 10.0, $p < 0.001$), dog-directed aggression (F = 8.71, $p < 0.001$) and chasing (F = 6.02,

$p < 0.001$) (Figure 2). Dogs classed as aggressive towards humans had the highest scores for stranger-directed aggression and dog-directed aggression, while both classes of aggressive dogs had higher scores for chasing compared to non-aggressive dogs. Non-aggressive dogs had the lowest scores in all four categories.

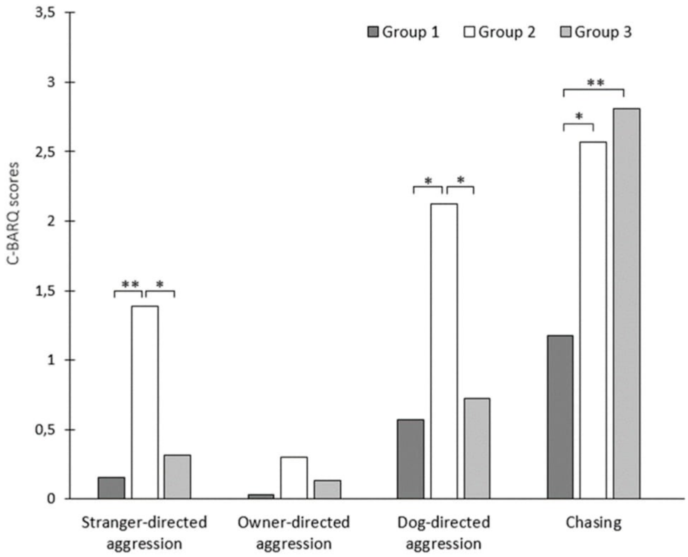

Figure 2. Owner-reported dog behavior using the C-BARQ questionnaire scoring by aggression groups (* $p < 0.05$; ** $p < 0.001$). Group 1 = non-aggressive dogs; Group 2 = dogs, aggressive towards humans; Group 3 = dogs, aggressive towards animals.

Looking at the personality assessment of dogs derived from the DMA, sociability was the only trait which differed statistically between the groups ($F = 4.5$, $p = 0.02$) (Table 1). Non-aggressive dogs had higher sociability scores compared to dogs aggressive towards humans ($p < 0.01$). The age of the dogs was found to have an effect on their personality traits. Older dogs were less playful ($F = 17.54$, $p = 0.0002$), less chase-prone ($F = 8.91$, $p < 0.005$) and more shy in the shyness/boldness dimension ($F = 12.14$, $p < 0.001$) than younger dogs.

Table 1. Differences between groups (Group 1 = non-aggressive dogs; Group 2 = dogs, aggressive towards humans; Group 3 = dogs, aggressive towards animals) in dogs' personality traits. Bold—statistically significant result. Means with different superscript letters differ significantly.

Personality Trait	Group	Mean	SD	F-Value	*p*-Value
Playfulness	1	3.64	1.55	1.96	0.16
	2	2.15	1.68		
	3	3.59	1.83		
Curiosity	1	3.76	0.89	0.14	0.87
	2	3.58	0.78		
	3	3.56	0.74		
Chase-proneness	1	3.75	1.49	1.48	0.24
	2	2.42	1.57		
	3	3.58	1.69		
Sociability	1	3.79^{a}	0.93	4.5	**0.02**
	2	2.58^{b}	0.94		
	3	3.19^{ab}	0.81		
Aggressiveness	1	2.11	0.68	0.73	0.49
	2	2.12	0.85		
	3	2.5	1.29		
Shyness/boldness	1	3.74	1.01	2.13	0.13
	2	3.69	1		
	3	3.48	1.09		

The owners' personality assessment revealed neuroticism as the only statistically different trait between the dog aggression groups (Table 2). Owners of dogs which were aggressive towards humans had higher scores for neuroticism compared to other owners (both comparisons $p < 0.05$). The gender ($F = 5.62$, $p < 0.02$) and age of the owner ($F = 4.81$, $p < 0.04$) was found to have an effect on the owners' personality traits. Male and older owners were less extraverted than females and younger owners. The younger owners had higher scores for openness than the older owners ($F = 9.78$, $p < 0.004$).

Table 2. Differences between groups (Group 1 = non-aggressive dogs; Group 2 = dogs, aggressive towards humans; Group 3 = dogs, aggressive towards animals) in owners' personality traits. Bold—statistically significant result. Means with different superscript letters differ significantly.

Personality Trait	Group	Mean	SD	F-Value	*p*-Value
Extraversion	1	3.71	0.67	1.14	0.33
	2	3.23	1.01		
	3	3.69	1.07		
Agreeableness	1	3.68	0.64	0.82	0.45
	2	3.38	0.92		
	3	3.38	0.92		
Conscientiousness	1	3.79	0.82	0.02	0.98
	2	3.77	0.67		
	3	3.73	0.75		
Neuroticism	1	2.5^{a}	0.89	3.85	0.03
	2	3.27^{b}	0.88		
	3	2.5^{a}	0.82		
Openness	1	3.46	0.79	0.31	0.74
	2	3.69	1.11		
	3	3.69	0.97		

Owners' attachment styles did not differ between the groups (avoidant attachment: $F = 0.38$, $p = 0.54$; anxious attachment: $F = 1.88$, $p = 0.17$). However, a correlation analysis revealed that dogs of owners with higher scores for anxious attachment were less aggressive towards strangers, more sociable and had lower scores for chasing (Table 3). Those owners whose scores for avoidant attachment were higher had lower scores for conscientiousness and owned dogs with higher scores for owner-directed aggression.

Table 3. Significant correlations between attachment style, dog and owner personality traits and dog aggressive owner-reported behavior.

Attachment Style	Variable	r	*p*-Value
Anxious	Stranger-directed aggression	−0.4	0.01
	Chasing	−0.37	0.03
	Sociability	0.33	0.05
Avoidant	Owner-directed aggression	0.38	0.02
	Conscientiousness	−0.42	0.01

Within each of the aggression groups, significant correlations were found between the observed variables (Figures 3–5). In the group of non-aggressive dogs (Figure 3), more extraverted owners had dogs with lower scores for chasing behavior. More playful dogs were more sociable, chase-prone and fearless. In the group of dogs which were aggressive towards humans (Figure 4), dogs with higher stranger-directed aggression were less sociable and less aggressive towards the owner. More neurotic owners were associated with dogs expressing a higher level of chasing behavior. In the group of dogs which were aggressive towards dogs and other animals (Figure 5), dogs with more expressed dog-directed aggression had less open owners. More conscientious owners were found to be less open and had lower scores for avoidant attachment and more playful dogs were found to be more chase-prone.

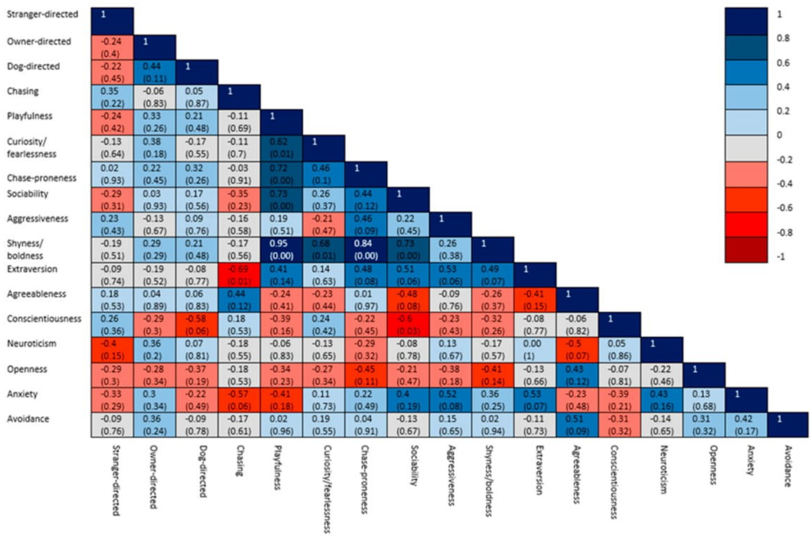

Figure 3. Correlation matrix of the coefficients of the variables in the group of non-aggressive dogs, with significance levels in brackets.

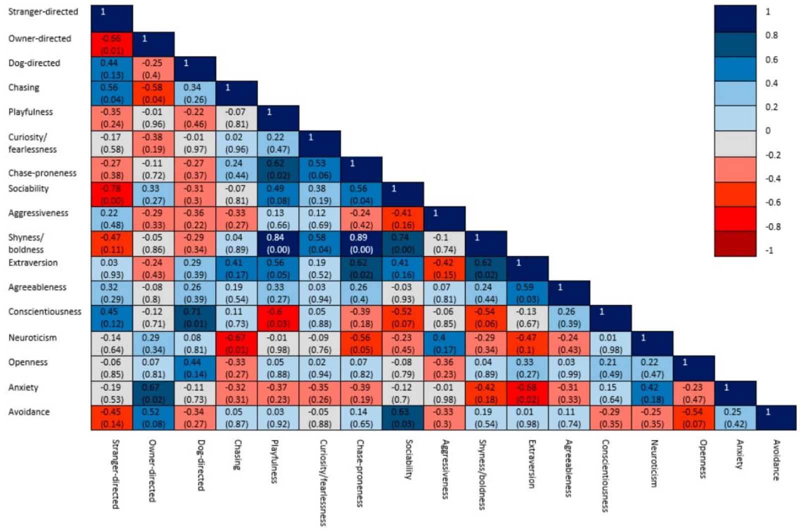

Figure 4. Correlation matrix of the coefficients of the variables in the group of dogs which were aggressive towards humans, with significance levels in brackets.

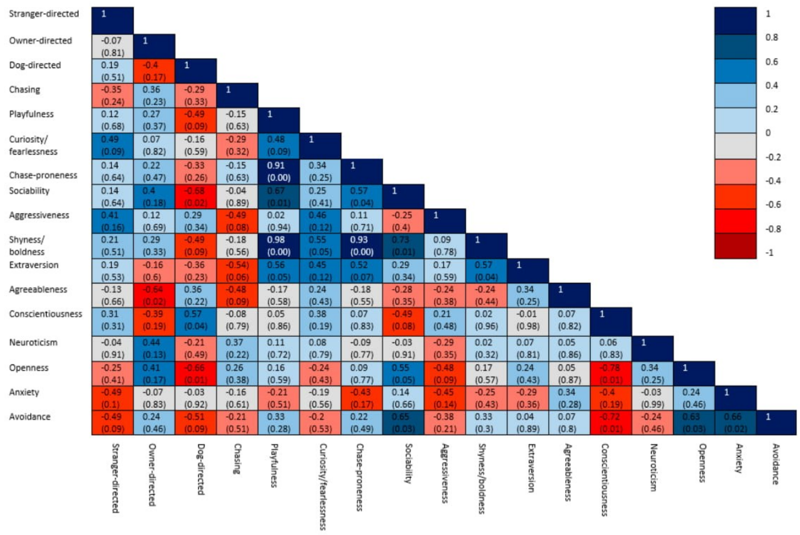

Figure 5. Correlation matrix of the coefficients of the variables in the group of dogs which were aggressive towards dogs and other animals, with significance levels in brackets.

4. Discussion

Using a combination of behavioral testing of the dog, and owner-reported questionnaires, our findings show that dog and owner personality profiles were strongly associated with dog aggression. Dogs classed as aggressive towards humans were found to be less sociable and had owners with higher scores for neuroticism. Our main results also reveal a previously unreported relationship between an owner's insecure attachment style to a dog and dog aggression. We showed that high avoidant attachment of owners was associated with high levels of owner-directed aggression, while a high anxious attachment was associated with low levels of stranger-directed aggression.

When examining the relationships between dog personality scores and owner-reported dog aggressive behavior, sociability was the only personality trait associated with the behavior. Dogs classified as aggressive towards humans had lower sociability scores than non-aggressive dogs. Furthermore, within this group, a correlation analysis revealed that less sociable dogs were more aggressive towards strangers. This is in line with previous findings showing that high scores for sociability are linked to lower levels of stranger-directed and child-directed aggression in dogs [23]. It seems that sociable dogs are more comfortable around strangers and in new environments, resulting in lower stress levels and a better social control that may reduce aggressive responses [41]. A personality trait positively associated with sociability in our study was playfulness, but only in the group of non-aggressive dogs. Finding this association only in the group of non-aggressive dogs implies that the social evolutionary purpose of play is a normal social behavior. The function of social play is to enable a more flexible development of future behaviors and a better socio-cognitive development [42,43] with the improvement of communication skills and social ties [44,45]. Play may thus contribute an important role in the appropriate (non-aggressive) social behavior of dogs. Furthermore, playfulness was also positively associated with chase-proneness in the groups of non-aggressive dogs and dogs which were aggressive towards animals, which was previously reported by Svartberg [46] while validating dog behavioral traits.

When considering the owners' personality traits, neuroticism was the trait found to have the main impact on the manifestation of dogs' behavioral problems. The dogs of more neurotic owners were characterized as being the most aggressive of all the dogs towards both strangers and dogs. In the group of dogs classified as showing aggressive behavior towards humans, high owner scores for neuroticism were associated with more prominent chasing behavior in the dog. The reason behind this may be found in the fact that owners' neuroticism may affect the social behavior of their pet, causing behavioral problems and/or aggressive behavior [47]. A second relevant, although less influential, personality trait was conscientiousness. In the group of dogs classified as showing aggressive behavior towards animals, owners scoring high on conscientiousness were less open. The less open owners were younger individuals who had dogs with higher levels of owner-directed aggression. More conscientious individuals tend to be more organized, responsible and self-disciplined [48], which possibly makes them more controlling, leading to a dog which is less prone to engage in play with a stranger. The other explanation could be that highly conscientious and neurotic individuals tend to prefer dog breeds they perceive as more aggressive [49]. Looking at the owners' neurotic personality trait, similar positive associations to those found in our study between neurotic owners and behavioral problems, such as the aggression of pets, have been reported in another dog study [50], and in cats [47], as well as in humans [51]. According to Schöberl et al. [52], who suggested that neurotic individuals have a higher stress level based on higher cortisol levels, and Finka et al. [47] recently claimed that neurotic owners affect their pets' behavior by being less warm, more hostile and overall displaying unpredictable styles of caretaking, resulting in higher stress levels and decreased social control of their cat. We may therefore argue that these neurotic dog owners have a specific behavioral and physiological profile that affects their pets. Another relevant personality trait, however seen only in the non-aggressive dog group, was extraversion, with more extraverted owners, mostly younger females, having dogs with lower levels of chasing. As extraverted people are more inclined to attend various social events and activities, socialize and enjoy the company of other people [53], it is possible that they include their dogs in these activities, making dogs more socialized to other people and animals, and more comfortable in new environments, which might have resulted in a lower level of chasing.

The finding that owners with higher scores for neuroticism were associated with aggressive dogs partly supports our hypotheses. We based our hypotheses on the study by Dodman et al., [24], where

1564 people responded to an online battery of questionnaires and where it was concluded that owners with lower scores of extraversion, agreeableness, conscientiousness and emotional stability (high neuroticism) own dogs which are more susceptible to develop owner-directed aggression. Although our sample size may have limited the ability to detect potential associations between owners' personality traits and dog behavior, adding behavioral testing of dogs to objectively assess aggression-related traits enabled our data to be without possible owner biases, and thus more reliable. Questionnaires are known to be a less reliable, less objective method of assessment, although they are less time consuming to administer [19]. It may thus not be surprising to see differences between our results and those in literature, because all previous studies were done using questionnaires only [25,54,55], or even the same Big Five factor taxonomy in both dog and owner assessments [25], just to be able to easily compare dyad scores.

In this study we are first to confirm a relationship between owners' attachment style to pets and dog aggression. Before discussing this further, it is important to note that we assessed the owners' attachment to their dogs, while in other studies mentioned below, the adult attachment styles to other people were used for studying the relationship between owners' attachment and their pet's behavior. We showed that both degrees of the insecure attachment styles, anxious and avoidant, play a role in dog aggression, regardless of a dog being identified by their owner as a non-aggressive dog, a dog aggressive towards humans, or a dog aggressive towards animals. The owners whose scores for avoidant attachment were higher had lower scores for conscientiousness and owned dogs with higher scores for owner-directed aggression. This can partly be explained by the idea that a more avoidant attachment style to pets might influence the owner's behavior toward their dog as they distance themselves from the dog, being ignorant and not providing enough affection, intimate contact and availability, as seen in adult attachment [56]. As a result, the dog may perceive a lack of consistent responsiveness to its needs as an indication that it cannot use its owner as a secure base, as it was previously suggested that owners can represent a secure base for their dogs [57], especially in a threatening situation [36,58]. This might evoke fear in dogs, which is one of the most common motivations for aggressive behavior [10]. Security gained from a caregiver may reduce or eliminate the level of fear in dogs. Similar behavioral responses to those we found have been reported in children of parents with a more avoidant attachment style. Children tended to be less attentive toward their parents [59] and more distressed [60] during a stressful event.

On the other hand, and contrary to our hypotheses, dogs with higher scores for stranger-directed aggression were associated with owners who had lower scores for anxious attachment to pets. It seems that highly anxious attachment behavior of the owner, such as constant seeking of support and closeness, clinginess and controlling behavior [61], does not promote aggression. This is in contrast to studies in humans, where it has been reported that anxious mother–infant attachment increases the risk of child aggression [62]. It also seems that anxiety does not contribute to the lack of responsiveness [63] seen among people scoring higher in avoidant attachment, which can lead to a more stressful situation for the dog and potentially facilitate aggression. We also found correlations between owner attachment style to pets, and dogs' and owner's personality traits, as seen in human adults [64]. Contrary to our findings showing that more conscientious dog owners were associated with higher scores for avoidant attachment to dogs, Carver [64] found an association with extraversion, agreeableness and neuroticism. A further strong correlation was found between dog owners with high scores for anxious attachment and highly sociable dogs that are not prone to chase. Knowing that this attachment represents a tight, even clingy relationship between dog and owner, we may speculate that these dogs are used to closeness and proximity, resulting in also being more comfortable in the vicinity and company of other people.

By providing evidence of the associations between owner's attachment style to pets and dog aggression, this study can serve as a foundation for future research on psychosocial factors affecting dog aggression. We believe that owners' aggressive tendencies, dog training and socialization history and more in-depth exploration of the owner–dog bond are important psychosocial measures that can be further explored in the context of dog aggression. In this particular study, we used the personality taxonomy developed by Svartberg and Forkman [20] to investigate dog personality. However, there are other potentially useful measures (for review on dog personality assessment see Fratkin et al., [15]), yielding alternative dog personality traits that may potentially play a role in dog aggression.

5. Conclusions

Our results imply that both dogs' and owners' personality profiles predict dogs' aggressive behavior. Similar to previous studies, neuroticism as the personality trait of an owner and sociability as the personality trait of a dog were closely associated with dogs exhibiting human-directed and animal-directed aggressive behavior. We first provided evidence suggesting that owners' insecure attachment styles to pets, anxious and avoidant attachment, are linked to owner- and stranger-directed aggression in dogs, making owner–dog attachment style a potential predictor of undesired dog behavior. These results may contribute to the early detection of potentially dangerous traits, leading to better management and prevention of dog aggression towards humans, other dogs and other animals.

Supplementary Materials: The following are available online at http://www.mdpi.com/2076-2615/10/2/315/s1, Table S1: Score sheet for DMA.

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Supplementary Table

Table S1. Score sheet for DMA.

Subtest	Behavioural variables	Score	Description of behaviour
Social contact	Greeting reaction	1	Rejection of greeting
		3	Interest in greeting
		5	Intense greeting with jumping and whining
	Cooperation	1	Refusal to walk with stranger
		3	Willingness to walk with stranger, uncertain walk on a relaxed leash
		5	High willingness to walk with stranger
	Handling	1	Rejection of physical contact
		3	Physical contact is not rejected, no social behaviour toward the stranger
		5	Intense social behaviour towards stranger
Play 1	Interest in play	1	No interest in the tossing of the rag
		3	Interest in the tossing rag, but no following
		5	Active play and following of the thrown rag
	Grabbing	1	No grabbing
		3	Interest in the rag, following, but no grabbing
		5	Immediate and intense grabbing
	Tug-of-war	1	No biting at all
		3	Grabbing, but quick release of the rag
		5	Immediate grabbing the rag with twitches and fighting until the TL releases the rag
Chase	Following 1	1	No attempts to run after the fleeing object
		3	Notice of the fleeing object and not immediate run after
		5	Immediate reaction when seeing the object and running towards it with high speed
	Grabbing 1	1	No attempts to grab the object
		3	Grabbing of the object after more than 3s
		5	Immediate and intense grabbing combined with holding of the object in at least 3s
	Following 2	1	No attempts to run after the fleeing object
		3	Notice of the fleeing object and not immediate run after
		5	Immediate reaction when seeing the object and running towards it with high speed
	Grabbing 2	1	No attempts to grab the object
		3	Grabbing of the object after more than 3s
		5	Immediate and intense grabbing combined with holding of the object in at least 3s
Passive situation	Activity	1	Non-active
		3	Active behaviour at the beginning of the subtest and non-active after, or vice versa
		5	Active behaviour with switches between different modes of activity
Distance play	Aggression	1	No signs of aggression or threat display

		3	Mild aggression display (quiet growling, low posture)
		5	Threat display (growling, snarling, raised hackles, raised tail, etc.) directed against the assistant during both phase of threat and invitation
	Exploration	1	No approach attempts towards the assistant, even when he is actively calling the dog
		3	Approach after active calling
		5	Immediate approach, even to the passive assistant
	Tug-of-war	1	No attempts to play tug-of-war
		3	Play after invitation, passive grabbing of the rag
		5	Immediate attempts to play with active pulling even when assistant is passive
	Play invitation	1	No interest in the assistant
		3	Interest in the assistant when he is active
		5	Urgent play invitations from the dog to the assistant, even when he is passive
Sudden appearance	Startle reaction	1	A flight of > 5m
		3	A flight of < 5m
		5	Short hesitation
	Aggression	1	No signs of aggression, or threat display
		3	First reaction is attack against the dummy, no signs of aggression after
		5	Threat display and attacks against dummy
	Exploration	1	Great need of support (no approach of dummy until handler lowers it and sits close to it), or no approach
		3	Need of support
		5	Immediate approach to the dummy without need of support
Metallic noise	Startle reaction	1	A flight of > 5m
		3	A flight of < 5m
		5	Short hesitation
	Exploration	1	No approach of the sheet of metal, even if handler sits close to it
		3	Approach with handlers' support
		5	Immediate approach without need of support
Ghosts	Aggression	1	No signs of aggression or threat display
		3	Threat display during the approach but not during the appearance
		5	Threat displays and several attacks against the ghosts
	Attention	1	Occasional glances towards the ghosts
		3	Frequent staring towards ghosts
		5	Constant staring and activity towards ghosts during the whole period of approaching
	Exploration	1	No approach, at least not before step 4
		3	Approach during step 2 or 3
		5	Immediate approach after the dog is unleashed

Play 2	Interest in play	1	No interest in the tossing of the rag
		3	Interest in the tossing of the rag, but no following or play behaviour
		5	Active play and following of the thrown rag
	Grabbing	1	No grabbing
		3	Staring towards the rag, occasional following
		5	Immediate and intense grabbing

2.1.3 Dogs exhibiting high levels of aggressive reactivity show impaired self-control abilities

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Inhibitory control describes a multitude of cognitive processes that prevents an impulsive response and enables a more appropriate behavior in a given situation. The ability to inhibit undesirable behaviors, such as aggression, is particularly important in dogs for safe and successful interspecific interaction and cooperation. The present study investigated the associations between two aspects of inhibitory control in dogs, self-control and cognitive inhibition, and the tendency to respond aggressively when provoked. Sixteen police and fourteen privately owned dogs of the same sex, breed group and similar age participated. Self-control, often described as impulsivity, was measured with an exchange paradigm themed the delay of gratification test, and cognitive inhibition with an object discrimination paradigm called the reversal learning test. Aggressive reactivity was assessed with a standardized aggression-eliciting behavior test. When comparing police and privately owned dogs, police dogs showed higher aggression levels and poorer self-control, while the two groups did not differ in cognitive inhibition. Regardless of the dog group, the main results indicated impairments in self-control in dogs with high levels of aggressive reactivity. Dogs showing biting behavior had worse self-control abilities compared to dogs with no signs of aggression. No association between cognitive inhibition and aggression was found. We conclude that self-control, measured as the ability to tolerate delayed rewards, appears to be an important aspect of inhibitory control involved in the tendency to respond aggressively, particularly in police dogs.

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Dogs Exhibiting High Levels of Aggressive Reactivity Show Impaired Self-Control Abilities

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Inhibitory control describes a multitude of cognitive processes that prevents an impulsive response and enables a more appropriate behavior in a given situation. The ability to inhibit undesirable behaviors, such as aggression, is particularly important in dogs for safe and successful interspecific interaction and cooperation. The present study investigated the associations between two aspects of inhibitory control in dogs, self-control and cognitive inhibition, and the tendency to respond aggressively when provoked. Sixteen police and fourteen privately owned dogs of the same sex, breed group and similar age participated. Self-control, often described as impulsivity, was measured with an exchange paradigm themed the delay of gratification test, and cognitive inhibition with an object discrimination paradigm called the reversal learning test. Aggressive reactivity was assessed with a standardized aggression-eliciting behavior test. When comparing police and privately owned dogs, police dogs showed higher aggression levels and poorer self-control, while the two groups did not differ in cognitive inhibition. Regardless of the dog group, the main results indicated impairments in self-control in dogs with high levels of aggressive reactivity. Dogs showing biting behavior had worse self-control abilities compared to dogs with no signs of aggression. No association between cognitive inhibition and aggression was found. We conclude that self-control, measured as the ability to tolerate delayed rewards, appears to be an important aspect of inhibitory control involved in the tendency to respond aggressively, particularly in police dogs.

Keywords: dogs, police dogs, inhibitory control, delay of gratification, reversal learning, aggression

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INTRODUCTION

Aggression can be observed in a variety of species and can be defined as a behavior that inflicts or threatens physical or psychological harm (1). In dogs, it is generally expressed as aggressive biting behavior, by snapping or attacking, and aggressive threatening behavior, by growling, barking, and baring their teeth (2). Although it is one of the normal social behaviors of dogs (2), aggression represents one of the most dangerous and undesirable behaviors in certain contexts, especially when directed toward humans. The ability to respond non-aggressively facilitates interactions with humans and allows the development of relationships (3–5). Therefore, further understanding of aggression may be important for animal welfare, public safety, and improved dog-human cooperation.

The most objective way to assess aggression in dogs in a control environment is to use standardized behavioral tests known to assess aggressive reactivity (i.e., the tendency of dogs to respond aggressively), such as Socially Acceptable Behavior (SAB) test (6). The validation of the SAB test revealed that the behavior shown in the test is highly associated with the dogs' past and future behavior. Therefore, it is suitable to assess behavioral phenotypes by including dogs with different behavioral backgrounds. For example, the selection of dogs in the study presented in this manuscript was based on Haverbeke et al. (7), who found frequent aggression of military dogs in the SAB test and on our previous findings, which showed that privately owned but highly trained dogs rarely expressed aggression in the SAB test (8).

There is recent evidence showing that canine aggression is associated with a number of psychological and cognitive factors. For example, it may be associated with various dog and owner personality traits (9, 10), temperament (11), attachment styles (10), impulsivity (5), and cognitive impairment (12). Another cognitive mechanism proposed to play a role in aggression is inhibitory control, referred to as the ability to interrupt the execution of an immediately enticing but detrimental behavior in favor of a delayed but more rewarding behavior (13). Reduced inhibitory control ability has been reported to be associated with aggression and violence in human adults (1, 14) and children (15). Although it has been previously suggested that dogs have the ability to inhibit behaviors unwanted by their owners (4), there are large gaps in knowledge regarding the association between aggression and inhibitory control.

Inhibitory control in dogs is usually measured using simplified versions of tests developed for humans [e.g., (16)] and non-human primates [e.g., (17)]. Using different tests, both human (18) and canine (13, 19, 20) researchers found that the tests did not correlate with each other, but appeared to be context-specific. The lack of correlation suggests that the individual tests measure different aspects of ability, suggesting that inhibitory control is a collection of distinct cognitive processes rather than a unified mechanism (19, 21). Therefore, it is important that it is captured with multiple tests, each targeting different aspects of this ability. Three aspects of inhibitory control are commonly described in dogs: motor inhibition, self-control, and cognitive inhibition (19, 22). Self-control and cognitive inhibition are aspects known to be associated with human aggression (23, 24), but it is not known whether such an association exists in species such as dogs.

Self-control is the ability to tolerate a certain effort in order to obtain a better outcome [see (21) for a review], and it is proposed to be an important determinant of whether an individual overrides or responds to an urge to react aggressively (25). It is commonly measured using an exchange paradigm called the delay of gratification test, in which an individual must abstain from a less preferred reward and wait for a better but more delayed reward (26). It has been suggested that the ability to inhibit a prepotent response is evidence of better self-control because it leads to receiving more or a better quality reward (21). To our knowledge, the ability to tolerate delayed rewards has not yet been studied in the context of canine aggression, but studies in humans (24) and rats (27) have shown that aggressive individuals show less self-control.

Cognitive inhibition, on the other hand, is the ability to regulate the content of working memory by blocking information irrelevant to the task (28). It is often measured using an object discrimination paradigm called the reversal learning test, in which two stimuli change their reward contingencies after initial discrimination learning (29). The test measures flexibility in relearning object-reward contingencies, but also the ability to inhibit a learned response and avoid the previously rewarded option (19, 29). Again, this paradigm has not yet been used in the context of canine aggression, but impairments in reversal learning have been associated with aggression in humans (23).

We focused on the two aspects of inhibitory control, self-control and cognitive inhibition, and we aimed to investigate their association with aggressive reactivity in dogs, using a standardized behavioral test and two separate tests of inhibitory control. Based on studies in humans and rats, we predicted that dogs would show limited inhibitory control in both tests when characterized as more aggressive during aggression-eliciting stimuli. Compared to privately owned dogs, we predicted that police dogs would exhibit higher level of aggression and poorer cognitive performance, because outside of their working environment they often display impaired self-control (30).

MATERIALS AND METHODS

The Administration of the Republic of Slovenia for Food Safety, Veterinary Sector and Plant Protection approved the study (U34401-17/2020/10). All participants signed a consent form and were given the right to withdraw from the study at any time. We hereby confirm that the study was performed in accordance with the relevant guidelines and regulations.

Animals

Thirty dogs (**Supplementary Table 1**) participated in the aggression and two inhibitory control tests. Included dogs had different aggression-related behavioral phenotypes, but comparable demographic characteristics. They were either privately owned and were highly trained or had various working functions ($n = 14$) or were police dogs at the process of training, not specialized in a particular working task ($n = 16$). Privately owned dogs lived at owner's home ($n = 14$), while the police dogs lived either at handler's home ($n = 4$), in kennel ($n = 7$) or the combination of the two ($n = 5$) (**Supplementary Table 1**). All dogs were male, between 12–36 months of age (mean age: 22.00 ± 6.65 months) and from the same classified breed group—sheepdogs (Fédération Cynologique Internationale) and except two privately owned dogs, all others were neutered. Similar age and breed of dogs mitigate the effect of age (31) and breed (32) on inhibitory control performance. Males were chosen because majority of police dogs in the country are males. From previous research it is known that male dogs have a higher probability of aggression than females (33), making them more suitable to study in the context of aggression.

Procedure

The testing was conducted between July and October 2020 at the two different sites. Using the same equipment and procedures, police dogs were tested at the site of the Ministry of Interior of the Republic of Slovenia and privately owned dogs were tested at the Biotechnical Faculty of the University of Ljubljana. Due to police dogs availability and logistical limitations, mainly including the size and installation of the outdoor test area, all dogs first participated in the aggression test. About 2 weeks later, inhibitory control testing was performed in an empty indoor test room (5 × 6 m) unknown to the dogs. Following the procedure and set-up modified after Brucks et al. (19), self-control was measured with the delay of gratification test and cognitive inhibition was assessed with the reversal learning test. Due to limited availability of indoor space because of COVID-19 restrictions, both were administered on the same day. There was approximately half an hour rest period between tests and the owner/handler was allowed to walk the dog outside or freely interact with the dog inside (e.g., if the weather was bad). The order of testing was counterbalanced and randomized for all dogs. To control for fatigue and satiation, the order of testing, number of trials and quantity of food the dog received were noted down. None of the dogs had been previously trained for these specific tests. Immediately before the test, the owners/handlers were informed how to follow the experimenter's instructions, and the dogs were allowed to explore the room freely for 2 min. During the test, which was videotaped, only the owner/handler and a female experimenter (not the same person performing the aggression test) were present in the room. The owners/handlers were passive during the tests, except when instructed to release and call back their dog.

TABLE 1 | Descriptions of 16 socially acceptable behavior subtests from Gobbo and Zupan Šemrov (8).

Subtest	Description
1	The dog is approached by one tester and petted with an artificial hand
2	The dog is exposed to an unfamiliar visual stimuli (a blanked is pulled up and down)
3	The dog is exposed to an unfamiliar visual stimuli (sudden appearance of a cat on a sledge)
4	The dog is exposed to an unfamiliar sound (sudden activation of a horn)
5	The dog is exposed to an unfamiliar sound (sudden rattle of metal cans)
6	The dog is slowly approached and surrounded by three testers
7	The dog is rapidly approached and surrounded by three testers
8	The dog is approached by one tester with a dummy dog
9	The dog is slowly approached by one tester and petted using an artificial hand
10	The dog is exposed to an unfamiliar sound (a bell is rang in front of the dog)
11	The dog is exposed to an unfamiliar visual stimuli (an umbrella is rapidly opened and closed in front of the dog)
12	The dog is exposed to an unfamiliar visual stimuli (a life-sized doll, standing on top of a sledge is pulled in front of the dog)
13	The dog is approached by one tester and petted with a doll fixed on a pole
14	The dog is approached by one tester staring.
15	The dog is approached by the same tester as in subtest 14 and petted with an artificial hand
16	The dog is approached by the owner or handler and petted with a doll

Aggression Test

Aggressive reactivity was assessed using the SAB test (6). Dogs were subjected to 16 subtests containing stressors known to elicit aggression in dogs. Descriptions of the subtests are presented in the **Table 1**. The test was performed outdoors in an enclosed test area of 700 m^2 (8). The owner/handler passively guided the dog on a leash during subtests 1–7 and 16 and was absent during subtests 8–15, when the dog was alone and attached with a fixed leash. Three female experimenters performed the test; the lead experimenter guided the owners/handlers through the test and the other two performed the subtests. Subtests were videotaped and aggression was scored using the scoring method developed by van der Borg et al. (34). For each subtest, aggression was scored on a 3-point scale, with 0 points awarded when there was no evidence of aggression, 1 point for threatening behavior (e.g., growling, baring teeth), and 2 points for attacking behavior (e.g., snapping, biting). The dogs were assigned into three categories, depending on the aggression level displayed; no aggression (received 0 point on all the subtests), only threatening behavior (received a score 1 on at least one of the subtests) or biting behavior (received a score 2 on at least one of the subtests).

Delay of Gratification

The delay of gratification test, described in Brucks et al. (19), measured self-control as the ability to forgo eating an accessible but low-quality reward (LQR) and wait for an inaccessible but high-quality reward (HQR). The test consisted of three parts: food preference test, training trials, and test sessions. To determine an LQR and HQR for each dog, the food preference test was conducted.

Different types of LQR (e.g., dry food) and HQR (e.g., sausage) (**Supplementary Table 1**) were cut into pieces (∼1.5 × 1.5 cm). Based on owner/handler reports of their dogs' food preferences, one piece of LQR and one piece of HQR were placed on two separate, identical plastic bowls (height: 10 cm, diameter: 15 cm). The experimenter, positioned in front of the dog simultaneously moved the bowls attached to a 1 m pole toward the dog held on a leash by the owner/handler so that the dog could sniff them. The bowls were moved laterally (∼1 m equidistant from the dog) and the dog was released and allowed to choose a bowl (i.e., eat the reward). This procedure was repeated twelve times, alternating sides of the LQR and HQR reward. If the dog chose the reward with the same quality at least nine times, that reward was considered its HQR and the less preferred reward was considered its LQR. If the dog did not choose the same reward at least nine times, the food combination was changed and the procedure was repeated.

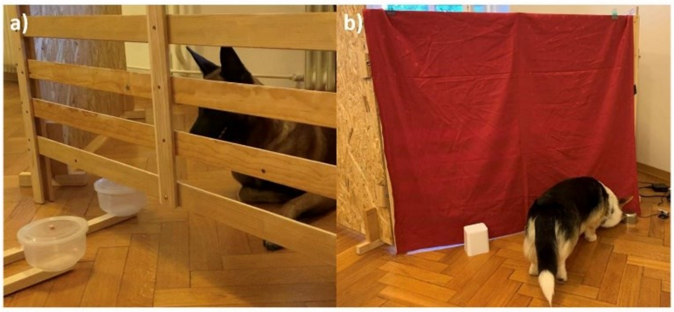

FIGURE 1 | (a) Setup and bowls position for the delay of gratification test. The dog refrains from selecting the accessible LQR and waits for the HQR, which enters the enclosure after a certain delay. **(b)** Design and location of the bowls for the reversal learning test. The dog selected the metal bowl by approaching and touching it. Immediately thereafter, the experimenter, hidden behind the curtain, lifted the bowl to show whether it contained the reward.

After LQR and HQR were determined for each dog, the training trials followed. The owner/handler and dog entered a wooden test enclosure (2 m^2), build out of three wooden frames (**Figure 1a**). The sides were covered in wood and the front part of the enclosure had an opening at the bottom through which two identical plastic bowls (the same shape as for food preference test) attached to a 1 m pole could be moved in and out. The experimenter, hidden behind a curtain, manipulated the two round plastic bowls, about 40 cm from the fence, and observed the dog via a webcam attached to the side of the enclosure. The movement of the two bowls was always as follows: Both bowls were pushed simultaneously toward the opening at the bottom of the fence so that both were visible but unreachable to the dog. Next, the bowl with the LQR entered the enclosure (until the whole bowl was inside, as shown in **Figure 1a**) and when the dog did not eat the reward, the bowl with the LQR was replaced by the bowl with the HQR after 2 s. Training was performed in order to familiarize the dog with the movement of the bowls and consisted of two types of trials: demonstration trials and test trials.

During the five demonstration trials, the owner/handler held the dog by the collar and prevented the dog from eating the immediately available LQR and released the dog when the LQR dish was withdrawn from the enclosure after a delay of 2 s and replaced with the HQR dish. During the test trials, the owner/handler remained passive and the dog was free to choose whether to eat the LQR immediately or wait for the HQR. The inter-trial interval was ∼8 s. If the dog chose the HQR in at least three test trials, it proceeded to the next part of the test. If not, the training was repeated. If the dog did not reach the criterion within three trials, it did not progress to the last part of the test and its participation in the test was terminated.

The final part of the test, the test sessions, consisted of two parts, the demonstration sections and the main part of the test with increasing delay durations between LQR and HQR. To familiarize the dog with the delay duration, each test session started with the four demonstration trials where the owner/handler prevented the dog from eating the LQR after entering the enclosure and released the dog when the LQR was replaced by the HQR. The owner/handler then left the enclosure and hid behind the curtain, leaving the dog alone for the main part of the test. Beginning with a delay period of 2 s, ten trials were conducted and the dog's ability to wait (i.e., not eating LQR) for HQR was observed. When the dog reached criterion (waited for at least three trials), it proceeded to the next delay stage. The delay time was increased to 5 s, then to 10 s, and finally to 20 s in each successive test session. The maximum delay stage was selected based on Brucks et al. (35) finding 20 s delay is a specific turning point for dogs' success in this paradigm. If the dog did not reach the criterion, the test session was repeated with the same delay time. If the dog did not reach the criterion within three test sessions or successfully waited in the 20 s delay, the test was terminated. The number of successful trials during the final part of the test, as well as the maximum delay time achieved, was observed. For a more detailed description of the test, see Brucks et al. (19).

Reversal Learning

Cognitive inhibition was measured as the ability to inhibit the previously learned response and shift the response to a new object-reward contingency, using the reversal learning test described in Brucks et al. (19). The test consisted of two phases; the acquisition phase and the reversal phase. The experimenter was hidden in a wooden enclosure covered with a curtain and observed the dog only via a webcam attached to the side of the enclosure. The owner/handler sat in a chair ∼2 m from the enclosure and held the dog by the collar. Two different bowls were used for this test, one was smaller (height: 6 cm, diameter 8 cm), round and made of metal, the other was larger (height: 12 cm, diameter 10 cm), white and made of plastic (**Figure 1b**). Each phase began with four warm-up trials with the goal of having the dog associate a bowl with a reward (positive bowl). Half of the dogs were randomly assigned the metal bowl as the positive bowl, and the other half were assigned the white bowl. The experimenter took a piece of sausage with her fingers and, put her arm under the curtain, waved, and placed the reward on the floor. She then placed the assigned positive bowl on the reward and removed her arm. The owner/handler released the dog and the dog was allowed to approach the bowl. As soon as the dog touched the bowl, the experimenter lifted the bowl and the dog ate the sausage. The owner/handler called the dog back and the procedure was repeated for three more trials.

After the warm-up trials, the first session of the acquisition phase began. The experimenter placed both bowls in front of the curtain at the same time (**Figure 1b**), and the dog was released. When the dog chose the positive bowl, the experimenter lifted the bowl and the dog ate the reward. When the dog chose the other bowl (negative), the experimenter lifted the bowl so that the dog could see that there was no reward. Immediately thereafter, the experimenter quickly lifted the positive bowl so the dog could see where the reward was hidden without giving them the opportunity to eat the reward. Then the owner/handler called the dog back. Each session within the acquisition phase consisted of twelve trials with 10 s inter-trial interval and the position of the positive and negative bowl was alternated. If the dog identified the positive bowl in at least nine trials [$p = 0.02$; (19)] within a session, it reached criterion and moved on to the next phase. If not, the next session was repeated after a short break. If the dog did not reach criterion within three sessions, the test was terminated.

After the acquisition phase was completed, the reversal phase followed. Both the warm-up trials and the reversal phase were conducted using the same procedure as in the acquisition phase, with the previous negative bowl now containing the reward. The reversal phase involved only one session, consisting of 12 trials. The correct choices (selection of the bowl containing the reward) during the acquisition and reversal phases were calculated separately. According to Brucks et al. (19), the main inhibition measure represented the ratio between the number of correct choices during the last acquisition (session during the acquisition phase when the dog reached the criterion; LA) and the reversal phase (RP) (LA/RP ratio). The time from release to choice during each trial during LA and RP was also noted.

Statistical Analysis

Frequencies (successful trials during the delay of gratification and correct choices during the RL) and continuous variables (time from release to choice during the RL) were coded using the Solomon coder (© 2019 by András Péter). Reliability coding was performed for 20% of the videos. The consistency between two coders for the continuous variable using an intraclass correlation coefficient was ICC > 0.88 and for the frequencies using Cohen's kappa was $\kappa > 0.95$.

Data were analyzed using SAS Software version 9.4 (Statistical Analysis Systems, SAS Institute, Cary, NC, USA). Normal distribution was determined using the Shapiro-Wilk test. With the exception of LA/RP ratio, the data distributions deviated significantly from the normal distribution, therefore non-parametric tests were used. Since all the dogs attending the test sessions in delay of gratification reached the maximum delay stage, the variable successful trials was treated as binary (dogs were either able or not able to delay gratification) and renamed to "success". The Wilcoxon signed-rank test was employed to compare median scores (correct choice and time) during LA and RP in the reversal learning test and Mann-Whitney *U*-test for number of trials and quantity of food. Two-tailed Chi-square test and Cramer's V were used to examine the relationship between categorical variables (success, test order, group).

To assess differences in performance between police and privately owned dogs, non-parametric GLIMMIX procedure (Generalized Linear Model for Mixed procedure) was utilized for success, taking into account a Binomial distribution. For the purpose of multiple comparisons, a Studentised Maximum Modulus method was used. For LA/RP ratio and aggression level, MIXED procedure was utilized. For the purpose of multiple comparisons, Tukey-Kramer test was utilized. For all models, dog within group was used as a random effect and group (police or privately owned dogs) as fixed effect. The order of testing, number of trials and quantity of food were also considered as fixed effects, but very high correlations were found between these three variables ($p < 0.001$) in both of the groups and age had low variation, therefore these variables were not included in the final statistical models. Housing condition was also considered as fixed effect in the model, but due to the structure of the factor in the two groups, it was not included.

To evaluate the relationship between inhibitory control measures and the aggression test, a correlation analysis was performed using the Kendall rank correlation coefficient. Data were standardized using the *z*-transformation (36) to compare variables on the same scale. Eta Coefficient test was used to determine the strength of association between performance in the delay of gratification (success) and the reversal learning (LA/RP ratio). Statistical significance was accepted when $p > 0.05$.

RESULTS

One police dog did not participate in the delay of gratification and the reversal learning test due to anxiety. Another privately owned dog failed to learn the task in the reversal learning test. This means that 29 dogs participated in the delay of gratification test and 28 dogs participated in the reversal learning test. The order of tests was not associated with performance in the delay of gratification (Cramer's $V = 0.11$, $p = 0.55$), nor reversal learning ($r = -0.09$, $p = 0.58$). Police and privately owned dogs did not differ in the quantity of food received ($Z = -0.02$, $p = 0.98$) and the number of trials the dogs participated during the first test ($Z = -0.02$, $p = 0.98$). The association between success in the delay of gratification and LA/RP ratio the reversal learning was weak ($\eta = 0.23$).

Delay of Gratification

During food preference test, the dogs needed between one and three sessions (mean: 1.63 ± 0.56), with 12 dogs (41.38%) having a preference during the first, 16 dogs (55.17%) during second and one dog (3.45%) during the third session. Out of 29 dogs, 17 dogs (58.62%) failed the training, 12 were police dogs. The 12 dogs (41.38%) that passed the training took an average of 2.38 ± 0.86 trials to reach the main part of the test. All 12 dogs successfully waited for the HQR during the delay phases and

TABLE 2 | Differences in performance during last acquisition and reversal phases in the reversal learning test.

Variable	Phase	Median	Range	Z-value	p-value
Time to make a choice (s)	Last acquisition	15.50	12.10–50.90	−4.64	**<0.001**
	Reversal phase	16.70	11.80–132.10		
Correct choices (number)	Last acquisition	10.00	9–11	−2.74	**0.006**
	Reversal phase	4.50	1–10		

Bolded values show significant associations.

TABLE 3 | Correlation between aggression level and z-transformed inhibitory control measures.

Test	Measure	Correlation coefficient	p-value
Delay of gratification	Success	−0.44	**0.013**
Reversal learning	LA/RP ratio	−0.24	0.13
	Correct choices LA (number)	0.09	0.63
	Correct choices RP (number)	−0.26	0.10
	Time to make a choice in LA (s)	−0.36	**0.025**
	Time to make a choice in RP (s)	−0.26	0.10

LA, last acquisition; RP, reversal phase. Bolded values show significant associations.

reached the maximum delay phase of 20 s. Throughout the test, the dogs waited between 24 and 42 trials for the HQR (median = 35.50 trials). Police dogs had significantly less success compared to privately owned dogs ($F = 5.02, p = 0.033$).

Reversal Learning

Dogs made a higher number of correct choices during LA compared to RP and the time from release to choice was shorter during LA compared to RP (**Table 2**). On average, the dogs required 1.86 ± 0.69 sessions to reach the criterion for participation in the reversal phase. Police and privately owned dogs did not significantly differ in LA/RP ratio ($F = 1.12, p = 0.30$).

Association Between Inhibitory Control and Aggression

When provoked with aggression-eliciting stimuli in the SAB test, eleven dogs (36.67%) showed no aggression during the test and received a score of 0, seven dogs (23.33%) showed only threatening behavior, and 12 dogs (40%) showed biting behavior at least once during the test. Police dogs displayed a significantly higher aggression levels compared to privately owned dogs ($F = 18.06, p < 0.001$). The dogs with higher aggression level had less success during delay of gratification test and took less time to make a choice during LA (**Table 3**).

Dogs showing distinct aggressive level differed in the success during delay of gratification test ($\chi^2 = 6.41, n = 29, p = 0.041$). Consideration of dogs that passed or failed training in the delay of gratification test revealed that of 17 dogs that failed training, 10 exhibited biting behavior, four exhibited threatening behavior, and three exhibited no aggression. Of the 12 dogs that passed the test, two showed biting behavior, three showed threatening behavior, and seven showed no aggression.

DISCUSSION

Focusing on two aspects of inhibitory control, self-control and cognitive inhibition, we investigated whether inhibitory behavior is associated with the occurrence of aggressive reactivity in dogs. In partial support our hypotheses, we found impairments in self-control, measured as poor performance in the delay of gratification task, but no effects of cognitive inhibition, measured with the reversal learning task, in highly aggressive individuals displaying biting behavior.

The results of the delay of gratification test need caution in interpretation due to the low variation in the performance. Because of that only failure or success were considered which may potentially limit the power of the results. Such performance was partially comparable to the results described in Brucks et al. (19). In both studies, more than half of the dogs were unable to pass the training and participate in the main part of the test, but our remaining dogs reached the maximum delay level compared to only 27 % in Brucks et al. (19). One of the explanations for this result could be found in the characteristics of the included dogs. We included mainly working or highly trained dogs, which, due to the nature of their work, are generally expected to have better cognitive performance compared to pet dogs (37) that participated in the other study. The other explanation could be the fact that we performed the test in 1 day, whereas in Brucks et al. (19) no more than three sessions were performed per day and the dogs had to continue the test on another day. Despite both tests being performed in 1 day, it appeared that order of testing, and consequently the number of trials a dog participated and quantity of food the dog received within the first test, did not affect the performance in the second cognitive test. Based on the self-depletion hypothesis, stating self-control in dogs relies on limited resources and once depleted, control of behavior becomes impaired (38), one could argue that our dogs would show impaired control of behavior following the delay of gratification test. However, our results showed that the participation in the delay of gratification did not affect further performance in the reversal learning test. Looking at the self-control results, dogs with the highest level of displayed aggression had the poorest performance in the delay of gratification tests.

This is consistent with studies in humans (24) and rats (27) showing that individuals who have impaired self-control often exhibit aggression. It is well-established that self-control is one of the neuropsychological concepts included in a number of higher-order cognitive processes and is referred to as executive control (39). Executive control is involved in the self-regulation of emotions and actions, including aggression. Building on this, our behavioral data are also consistent with neuroscientific studies reporting impairments in the neural circuits underlying emotion regulation and executive control in aggressive dogs (40) and aggressive humans (41).

Another mechanism mediated by executive control is impulsivity (42), which is often described in the context of canine aggression (5, 43, 44). While the association between self-control, measured as performance in delay of gratification test, and aggression has not yet been assessed in dogs, it has been proposed that delay of gratification test is an index of impulsive behavior and that lack of self-control in dogs may also be referred to as impulsivity (5). In Fatjó et al. (43) it has been reported that impulsive dogs have reduced or absent warning signs before exhibiting aggression. In our study, we found that dogs that have difficulty in tolerating delayed rewards showed impulsivity, as only the dogs that showed biting differed from dogs without aggression in their performance in the delay of gratification. Similarly, executive control measures have been reported to be associated only with violent, but not non-violent crimes in humans (45). In addition, our results support the findings of Wright et al. (5) in which using questionnaire data reported by owners to assess impulsivity as a trait, it was reported that dogs that scored higher on the impulsivity scale were more likely to express aggression. Despite using a different methodological approach, the results are likely comparable as it has been reported that performance during the inhibitory control test is closely related to owners' subjective reports of the dog's impulsivity (46). In general, the association between impulsivity and aggression found in dogs mirrors the results of studies in humans (47), non-human primates (48) and rats (48) and seems to be consistent in a variety of mammalian species.

During the reversal learning test, results showed that several components of executive functions were measured. The dogs' performance declined and decision time increased during the reversal phase, confirming that cognitive inhibition was successfully measured. As our dogs frequently chose the previously rewarded option without being rewarded, performance showed inflexibility [i.e., impaired capacity for changing strategies; (49)] and compulsivity [i.e., repetition independent of feedback; (19, 50)]. In humans, impairments in reversal learning have been associated with aggression (23) and more compulsive individuals have been associated with more frequent outbursts of aggression (51). In contrast to the human literature and our prediction, we found no association between reversal learning performance and severity of displayed aggression in dogs; however, several problematic issues arise when directly compared with human studies that examined reversal learning. First, most human authors study impairment in reversal learning in the context of psychiatric disorders, such as attention-deficit/hyperactivity disorder, obsessive-compulsive disorder, and psychopathy, as these individuals are known to show increased aggression (52). The studies have often involved children (53) and thus compare well to dogs, as children and dogs share similar cognitive mechanisms (54, 55), interpreting results in psychiatric patients compared to dogs is difficult.

Second, impairments in reversal learning are associated with reactive aggression in people with psychiatric disorders, with higher vulnerability to experiencing frustration being the main factor contributing to reactive aggression (56). It is difficult to draw a similar conclusion from our data and specifically in dogs, as frustration in dogs has mainly been studied as a consequence of absence, inaccessibility, or decrease in value of food (57, 58) rather than as an underlying mechanism of aggression.

Since aggression level has only been associated with performance in the delay of gratification and not the reversal learning test, and the association between the two cognitive tests was weak, our finding further supports the context specificity of inhibitory control previously reported in dogs (13, 19, 20). Also, since most of highly trained non-police dogs performed well in the delay of gratification test, this finding supports the executive control hypothesis, stating that specific self-control training improves impulsivity in other contexts (59, 60). The lack of association between inhibition and aggression performances could be explained by the variation in the skills that the dogs had to possess in order to be successful during the test. This variation is described as task demand (13, 20), as each test has different demands and requires different regulatory and decision-making skills. For example, the mere visibility of the reward may influence performance during the test (61), as individuals have greater difficulty self-regulating themselves when rewards are fully visible than when they are hidden (62). Therefore, it may not be surprising that only performance in the delay of gratification test, where the rewards were constantly visible, and not in the reversal learning, where the rewards were hidden, was associated with a particular behavior.

As expected, police dogs exhibited higher levels of aggression, confirming previous findings that the majority of military dogs show aggression in the SAB test (7), in parallel with poorer self-control performance in delay of gratification. This is not surprising, as impaired impulse control in military dogs has already been demonstrated in other contexts, e.g., unwanted aggression outside their working domain (30). Our further results revealed no difference in cognitive inhibition between the groups. Compared to results in pet dogs (19), our dogs showed better cognitive inhibition in the form of more correct choices during reversal learning, confirming previous findings that trained working dogs have better cognitive inhibition compared to non-trained pet dogs (60). Since we had dogs with different working and non-working training backgrounds, we can assume that any type of high-level training may be associated with better reversal learning performance.

Despite a number of studies reporting no sex differences in inhibitory control in dogs (13, 19, 22), a recent study (63) found that female dogs displayed better inhibitory control, making investigation of sex differences an interesting aspect for future research. In our study, the fact that the aggression test was performed first followed by two cognitive test on the same day may present a serious limitation. Further replication with an improved experimental design is advisable. Notwithstanding this limitation, we believe the current study can be used as a foundation for further research, as we were, to our knowledge, the first to investigate whether different aspects of inhibitory control play a role in the occurrence of aggressive reactivity in dogs. Although no association was found between cognitive inhibition and aggression, it appears that self-control was the aspect of inhibition associated with the dog's tendency to respond aggressively when provoked. Dogs that were able to inhibit impulsive behavior in the delay of gratification showed less or no aggression, demonstrating the association between impulsivity and behavioral inhibition. Including only one dog breed, our finding may be difficult to generalize to entire dog population. We believe that further research is needed regarding impulsivity and aggression for several reasons. First, aggressive dogs, especially those that show aggression without warning signs, can be a serious problem for many dog owners and others involved (64). Second, impulsivity is highly consistent over time (65), the ability to characterize impulsive behaviors that may lead to aggression at an early age may not only be important scientifically, but may also benefit the general population of dog owners.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The animal study was reviewed and approved by Administration of the Republic of Slovenia for Food Safety, Veterinary Sector and Plant Protection (U34401-17/2020/10). Written informed consent was obtained from the owners for the participation of their animals in this study.

AUTHOR CONTRIBUTIONS

EG and MZ: conceptualization, formal analysis, and writing—review and editing. EG: methodology, investigation, data curation, and writing—original draft preparation. MZ: supervision. Both authors read and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

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Supplementary Material

1 Supplementary Figures and Tables

Supplementary Table S1. Demographic data of the dogs.

No.	Age	Breed	Training	Housing	LQR	HQR
1	24	Border Collie	Non-working training	Home	Cornflakes	Sausage
2	20	Border Collie	Non-working training	Home	Cornflakes	Sausage
3	29	Belgian Shepherd	Search and rescue	Home	Cornflakes	Sausage
4	14	Border Collie	Non-working training	Home	Dry food	Sausage
5	24	Border Collie	Non-working training	Home	Dry food	Cheese
6	28	Australian Shepherd	Search and rescue	Home	Sausage	Dry food
7	15	Pembroke Welsh Corgi	Non-working training	Home	Cornflakes	Sausage
8	18	Rough Collie	Non-working training	Home	Dry food	Sausage
9	19	Swiss Shepherd	Non-working training	Home	Sausage	Dry food
10	25	Belgian Shepherd	Obedience	Home	Dry food	Sausage
11	36	Belgian Shepherd	Obedience	Home	Dry food	Sausage
12	24	Australian Shepherd	Herding	Home[1]	Cornflakes	Sausage
13	36	Australian Shepherd	Herding	Home[1]	Cornflakes	Sausage
14	36	Border Collie	Non-working training	Home	Cornflakes	Sausage
15	27	German Shepherd	Police	Home	Dry food	Sausage
16	27	German Shepherd	Police	Mixed	Cornflakes	Sausage
17	26	German Shepherd	Police	Mixed	Dry food	Sausage
18	15	German Shepherd	Police	Kennel		
19	26	German Shepherd	Police	Home	Cornflakes	Sausage
20	21	German Shepherd	Police	Mixed	Cornflakes	Sausage
21	21	Belgian Shepherd	Police	Home	Dry	Sausage
22	21	Belgian Shepherd	Police	Home	Cornflakes	Sausage
23	19	Belgian Shepherd	Police	Mixed	Cornflakes	Sausage
24	19	Belgian Shepherd	Police	Mixed	Cornflakes	Sausage
25	15	German Shepherd	Police	Kennel	Cornflakes	Sausage
26	15	German Shepherd	Police	Kennel	Cornflakes	Sausage
27	15	German Shepherd	Police	Kennel	Dry	Sausage
28	15	German Shepherd	Police	Kennel	Dry	Sausage
29	15	German Shepherd	Police	Kennel	Cornflakes	Sausage
30	15	German Shepherd	Police	Kennel	Dry	Sausage

LQR = low quality reward, HQR = high quality reward, Home[1] = outdoor living, Mixed = living at handler's home and in kennel

2.1.4 Neuroendocrine and cardiovascular activation during aggressive reactivity in dogs

Gobbo E., Zupan Šemrov M. 2021. Neuroendocrine and cardiovascular activation during aggressive reactivity in dogs. Frontiers in Veterinary Science, 8: 683858, doi: 10.3389/fvets.2021.683858: 12 p.

Our aim was to investigate cardiovascular activation by measuring changes in facial and body surface temperature using infrared thermography, and neuroendocrine activation using salivary cortisol (CORT) and serotonin concentration (SER) in dogs exhibiting aggressive reactivity in real time. Based on two factors, owner-reported past aggressive behaviors, and detailed behavioral observations collected during a Socially Acceptable Behavior test consisting of 16 subtests and, each individual was categorized as aggressive or non-aggressive. CORT and SER showed no difference in neuroendocrine activity between dogs, but aggressive dogs with higher levels of aggression were found to have lower SER. Aggressive dogs also had an increase in facial temperature from pre-test values. The discovery of a correlation between tail wagging and left tail wagging with aggression level and aggression-related behaviors in aggressive dogs is further evidence of the right hemisphere specialization for aggression previously reported in the literature. This study provides the first evidence that both cardiovascular and neuroendocrine systems are activated during an active act of aggression in dogs.

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ORIGINAL RESEARCH
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Neuroendocrine and Cardiovascular Activation During Aggressive Reactivity in Dogs

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Our aim was to investigate cardiovascular activation by measuring changes in facial and body surface temperature using infrared thermography, and neuroendocrine activation using salivary cortisol (CORT) and serotonin concentration (SER) in dogs exhibiting aggressive reactivity in real time. Based on two factors, owner-reported past aggressive behaviors, and detailed behavioral observations collected during a Socially Acceptable Behavior test consisting of 16 subtests and, each individual was categorized as aggressive or non-aggressive. CORT and SER showed no difference in neuroendocrine activity between dogs, but aggressive dogs with higher levels of aggression were found to have lower SER. Aggressive dogs also had an increase in facial temperature from pre-test values. The discovery of a correlation between tail wagging and left tail wagging with aggression level and aggression-related behaviors in aggressive dogs is further evidence of the right hemisphere specialization for aggression previously reported in the literature. This study provides the first evidence that both cardiovascular and neuroendocrine systems are activated during an active act of aggression in dogs.

Keywords: dog aggression, physiology, cortisol, serotonin, surface temperature, tail wagging

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INTRODUCTION

The response of animals to environmental stimuli, often referred to as reactivity (1), varies from individual to individual. When exposed to challenges, animals adopt different individual behavioral strategies or coping styles that are stable over a longer time (2). An individual coping style is an adaptive strategy characterized by a set of behaviors and physiological responses to reduce the impact of a stressor and is characteristic of a particular group of individuals (2). Animals, including dogs, can be described as proactive or reactive copers (3) and exhibit behavioral patterns that can distinguish them as aggressive or non-aggressive individuals, respectively (4). Aggressive reactivity in dogs, especially when directed toward humans, is a widely recognized problem that poses a public health and animal welfare concern (5). The behavior can be classified by its' motivation (territorial-, fear-related etc.) or target (human-, dog-directed etc.), but its' cause cannot always be determined. To date, various physiological factors underlying aggressive behavior have been studied to identify potential biomarkers of aggression, but certain gaps remain. Research (6–9) has primarily focused on comparing groups of dogs with or without a history of owner reported aggressive behavior, and has not aimed to examine physiological activation during an aggressive act. Evidence that considers physiological activation during an actual aggressive reactivity is therefore lacking. For the study of real-time behavior, it is recommended to measure multiple physiological parameters simultaneously (10), non-invasively, so that measurement devices and procedures do not interfere with behavioral responses (11).

Behavioral reactivity to external stimuli has been reported to be associated with cardiovascular parameters such as heart rate (HR), heart rate variability (HRV), and (body and facial) surface temperature. For example, recent evidence suggests that dogs with a history of biting incidents have poorer autonomic regulation, resulting in lower resting HRV (7), while dogs exhibiting aggressive reactivity to threatening stimuli have decreased HRV and increased HR (12). This latter result was based on measurements collected after the stimulus was applied, when the dog was standing still to avoid motion artifacts. In addition to motion artifacts, many researchers agree that the measurement of HR and HRV in moving dogs has other limitations. Sudden bursts of muscle activity during movement can lead to poor electrode conduction (13) and loss of contact or displacement of the electrodes can cause false signals (14). Another limitation is that the monitor strapped around the dog's chest can be intrusive, especially for dogs that are not used to wearing it, so habituation by wearing a dummy monitor may be required (13). An alternative measure that avoids any direct interaction during exercise and potentially alters behavioral responses is infrared thermography, which has been recognized as a useful tool for assessing cardiovascular reactivity in animals, including dogs (15). Findings in animals (16) suggest that it can be used to measure temperature changes associated with positive and negative affective states, as affective states can cause vascular activity that produces changes in heat production and release that lead to changes in surface temperature.

In terms of reactivity during negative affective states, dogs have been shown to have lower nasal temperature while alert when kenneled compared to a home environment (17). Other animal studies showed a decrease in nasal surface temperature in response to threatening stimuli [monkeys: (11, 18)] and a decrease in ocular bulb and periocular area temperature exposed to various stressors [rabbits: (19)]. The only two studies that observed cardiovascular activity during an aggressive act in animals were by Boileau et al. (20) and Rigternik et al. (21) and they reported inconsistent results. Boileau et al. (20) reported a decrease in dorsal surface temperature in pigs during a fight, while Rigternik et al. (21) found no differences between the control group and aggressive dogs that showed human-directed aggression.

The above cardiovascular parameters are closely related to the autonomic stress response "fight or flight", which prepares an animal to react in a stressful situation (22). Simultaneously, cortisol, the primary stress hormone, is released (23) in conjunction with the production of the inhibitory neurotransmitter serotonin (24). Such neuroendocrine activation modulates cognitive and behavioral functions and determines coping behavior in humans (25) and in non-human animals (26). According to Bari and Robbins (27), serotonin helps both humans and animals to inhibit inappropriate learned behavior and choose adapted behavior. In humans, Montoya et al. (28) found that low serotonin concentration (SER) combined with high testosterone to cortisol concentration ratio (CORT) modulates impulsive aggression. Following owner-reported past aggressive behavior, researchers found that aggressive dogs had significantly lower serum SER levels (6, 8) and higher plasma CORT levels than non-aggressive dogs (9). These studies used an invasive approach when examining cardiovascular activity, which caused unnecessary stress to the animals (29). To avoid this, CORT and SER can be assessed by highly comparable saliva samples (30) and tested during short-term physiological reactivity (31).

Similar physiological reactivity is often reported in the expression of various behaviors. For example, fear and aggression in dogs have different behavioral expression but share similar neurochemistry, resulting in similar physiological reactivity (32). To observe physiological and behavioral parameters in a controlled environment, behavioral tests are the most objective research method. In our study, the Socially Acceptable Behavior (SAB) test, which is known to elicit aggression in aggressively-inclined dogs (33), was used to assess a dog's behavioral phenotype. This test is also known to have a very high predictability of dogs' future biting behavior and a very high correlation between dogs' biting behavior during the test and their biting behavior in the past (33). In our study, we focused on the expression of the behavior and not on motivation for such behavior or target. Police working dogs were selected for the aggressive group because, according to Haverbeke et al. (34), the vast majority of military working dogs behave aggressively during the SAB test. For the non-aggressive group, highly trained dogs (e.g., show, rescue, therapy dogs) known to behave calmly in a new and noisy environment and in the presence of unfamiliar people (35, 36), of the same sex and age were selected. According to the breed nomenclature of the Fédération Cynologique Internationale, the dogs studied were all from the same classified breed group - sheepdogs. A final chosen criterion for inclusion in the dog groups was the behavior shown during the test. We decided to categorize dogs as aggressive if they attacked at least once during the test (37). The dogs primarily placed in the aggressive dogs that failed to exhibit biting behavior and dogs in the non-aggressive group exhibiting biting behavior were excluded from the study.

To provide a comprehensive physiological profile of an aggressive dog, neuroendocrine and cardiovascular parameters were measured simultaneously and non-invasively during the behavioral test of aggressive reactivity. Our main predictions were that aggressive dogs would show neuroendocrine activation measured by increased salivary CORT, but decreased SER, with concomitant cardiovascular activation measured as decreased facial and body surface temperature.

MATERIALS AND METHODS

The study was carried out between July and October of 2020 in Ljubljana, Slovenia and was approved by the Administration of the Republic of Slovenia for Food Safety, Veterinary Sector and Plant Protection (U34401-17/2020/10). The dog owners and handlers signed an informed consent form and were given the right to withdraw from the study at any time if the dog showed signs of stress or without giving a reason.

Animals

Two groups of dogs (aged between 12 and 36 months) with different behavioral backgrounds participated in the study. The aggressive group consisted of 16 male German and Belgian Shepherd police dogs that were reported to have been aggressive during training in the past. The non-aggressive group consisted of 15 male herding dogs of different breeds, trained to behave calmly in new situations and with no known history of aggression by humans. All dogs were without cardiovascular or sensory problems and all, except two in the non-aggressive group, were neutered. The police dogs were recruited through the Slovenian Ministry of Interior, and the privately owned dogs were recruited through Slovenian dog clubs and social media. To reach the test site, 19 dogs that were used to traveling longer distances traveled by car, while others were housed in kennels at the site.

Behavioral Recordings

Aggressive reactivity was assessed using the Socially Acceptable Behavior (SAB) test (33). The SAB test consisted of 16 subtests (**Supplementary Table 1**) and was administered outdoors in a specially set up test area (**Figure 1**) adapted from Planta and De Meester (33). Each subtest lasted 20 s, with the time in between kept as short as possible. The test was performed by the 3 experimenters. The lead experimenter instructed the owner/handler and guided him through the test, while the other two performed the tasks (e.g., pulling up the blanket). The total duration of the test was approximately 10 min per dog, mainly depending on the dog's cooperation in taking the thermographic images after each subtest. For safety reasons, the dogs were equipped with a harness, a leash, and an additional fixed leash [in subtests (1, 6–16)]. The owner/handler was present during subtests 1 through 7 and 16 and either held the dog on a short leash or the dog was tethered with a double 1.5 m fixed leash.

Behavior was videotaped and coded using the Solomon coder (© 2019 by András Péter). Using the scoring method introduced by van der Borg et al. (37), an aggression and anxiety score was assigned to each dog. During each subtest, aggression was scored on a 3-point scale, with 0 points assigned if there were no signs of aggression, 1 point if the dog showed threat (e.g., growling, baring teeth, staring), and 2 points if the dog attacked (e.g., snapping, biting, lunging). Anxiousness was scored on a 5-point scale indicating whether the behavior was safe (0 points), unsafe (1 point), fearful (2 points), extremely fearful (3 points), and panicky (4 points). Scores were cumulative, with a maximum of 32 points for the aggression score and 64 points for the anxiety score. These scores represented the highest aggression and anxiety scores. More detailed behavioral reactivity during the SAB test was analyzed either as duration or frequency of occurrence using a predefined ethogram (**Table 1**).

Reliability coding was performed for 20% of the videos. The consistency between two coders for frequencies using Cohen's Kappa (κ) was 0.87 and for continuous variables using an intra-class correlation coefficient (ICC) was 0.96.

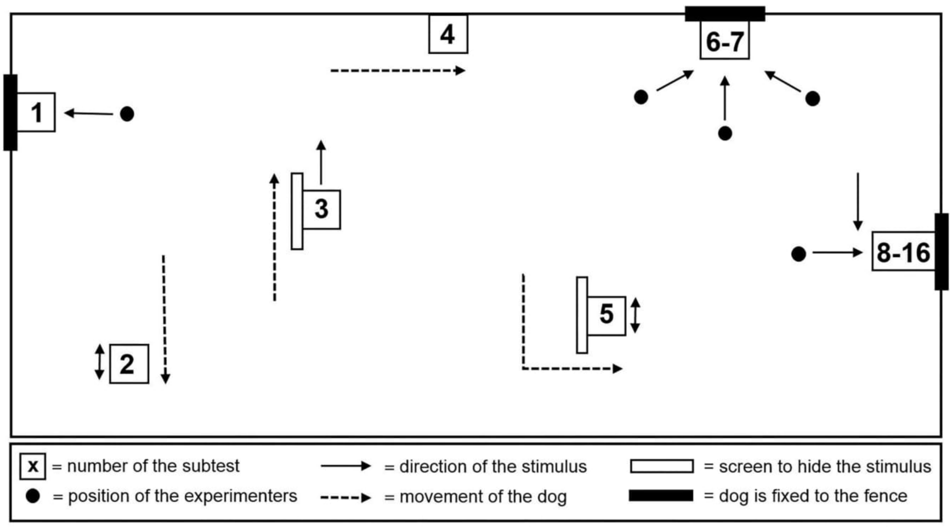

FIGURE 1 | Schematic plan of the test area.

TABLE 1 | Descriptive ethogram of the observed behaviors during SAB test.

Category	Behavior	Description	Scoring
Locomotion (37)	Moving	Moving with at least one step with each paw	Duration
	Standing	Standing upright, with all four paws on the ground (may move a maximum of two steps)	Duration
	Sitting	Behind is on the ground, forelegs are stretched and support the front of the body	Duration
	Lying down	All four legs and belly are in contact with the ground	Duration
Posture (34, 37)	High	Elevation of the head and/or pointed ears, tail position higher than neutral	Duration
	Neutral	As shown by dogs in neutral conditions, natural position of the tail	Duration
	Low	Bent legs, ears positioned backwards, tail position lower than neutral	Duration
Aggression (34, 37)	Staring	Gazing at the stimulus right in the eyes and freezing of the body	Frequency
	Baring teeth	Showing of the teeth by lifting the upper and lower lips, may be accompanied by nose wrinkling	Frequency
	Snapping	Fast biting movement toward the stimulus, quick head movement (may be accompanied by showing of the teeth, growling, barking), but no physical contact	Frequency
	Attacking	Fast, maximal movement toward the stimulus, biting movement with open mouth or actual bite (may be impossible due to the safety design), may be accompanied by showing of the teeth, growling, barking	Frequency
	Short bark	One single short barking sound	Frequency
	Rapid barking	Loud, repetitive barking sounds (3–4 barks per second)	Duration
	Growling	Low buzzing sound	Duration
	Growl-bark	Barking sounds preceded by growling	Duration
Fear/stress (37, 38)	Fleeing	Accelerated movement toward the opposite direction of the stimulus (more than 1 meter)	Frequency
	Retreating	Movement toward the opposite direction of the stimulus (up to 1 meter)	Frequency
	Stretching leash	Leash is stretched to the maximal length on the opposite direction of the stimulus	Frequency
	Snout licking	Tongue out and moving along upper lip or nose	Frequency
	Yawning	Widely opening of the mouth and inhalation	Frequency
	Whining	High pitched cyclic sounds	Frequency
Interaction with human (39)	Support seeking	Approaching or pushing toward the owner or the handler	Frequency
	Cover seeking	Hiding behind the owner, the handler, or something else with respect to the stimulus	Frequency
	Owner/handler seeking	Continuous gaze toward the direction of the owner or handler during subtest 8–15	Duration
Other behaviors (37)	Exploration	Nose positioned within 3 cm of any feature of the physical environment (testing stimuli excluded)	Duration
	Tail wagging	Movements of the tail, from central position to either side	Duration
		Left wag	Frequency
		Right wag	Frequency
	Play behavior	Human-directed play activities such as play bow or tug-of-war	Duration

Sampling and Data Collection of the Salivary CORT and SER

Saliva samples for the assessment of salivary CORT and SER were collected on three occasions. Samples in the home environment (home samples) were collected when the dog was relaxed and resting. Pre-test samples were collected immediately before the start of the SAB test (approximately 5 minutes after arrival at the test area), while post-test samples for SER were collected immediately after the behavioral test and for CORT were collected 20 minutes later, as the dog's CORT peaks approximately 20 minutes after contact with a stressor (40). Samples were collected using commercially available cotton swabs in plastic tubes (Salivette®, Sarstedt, Germany), following the procedure described by Glenk et al. (41). For safety reasons, saliva samples were collected by the owner/handler. To avoid contamination of the samples, the dogs were not allowed to eat or drink for 30 min before sampling and the person collecting the sample wore latex gloves. Cotton swabs were rotated in both sides of the dog's cheek pouch until saturated with saliva, for at least 30 s. The cotton swabs were used to collect samples. Swabs were examined for visible contamination before being placed in plastic tubes and temporarily stored in a freezer at −20 °C before final storage. The samples were stored for 2–3 weeks. To obtain clear saliva, swabs were thawed and centrifuged at 1,500 g for 15 min at room temperature.

Commercial enzyme immunoassay kits (Cortisol free in Saliva ELISA DES6611; Demeditec Diagnostic Gmbh Germany and Serotonin Research ELISA DEE5900; Demeditec Diagnostic

Gmbh Germany) were used for the determination of CORT and SER. ELISA kits have previously been used for CORT (42) and SER (43) assessment in dogs. Samples were tested in duplicate (1:10 dilution for SER samples). The sensitivity of the assay was 0.02 ng/mL for CORT and 0.005 ng/mL for SER. Although owners/handlers were familiar with the procedure, they were not always successful in collecting samples and from the total of 144 samples, saliva could not be extracted from 32 samples (22.2, 8.3% in the non-aggressive group and 13.9% in the aggressive group) due to limited sample volume. One outlier (home CORT in the aggressive group) exceeded the mean by more than 13 standard deviations and was removed from the statistical analysis.

Thermal Imaging Procedure

Surface temperature was measured three times using infrared thermography. Thermographic infrared images were taken with a portable thermographic camera (Optris PI 640). Images of the dog's facial area and body side were taken immediately before entering the test area (pre-test images) and immediately after the test was completed (post-test images). Body image were taken laterally, from a distance of approximately 2 m (from 1.8–2.5 m, depending on the dog's cooperation). The owner/handler stood sideways to the dog (out of the image) and held the dog by the leash. The side of the body from which the picture was taken was balanced between the dogs. Facial images were taken frontally, from a distance of 30–50 cm. Thermal images of the facial area (during the test images) were also taken during SAB the test, after completion of each subtest. As it is known that images taken in the field can be disturbed by the dog's coat characteristics, the distance between the subject and the camera, and environmental factors such as wind and humidity (44–46). Air temperature (°C), humidity (%) and wind (km/h) were measured before taking pre-test images of an individual dog. Dog characteristics (body weight, coat length, and coat color) were also recorded. Thermal images were analyzed using Optris PI Connect software (Rel. 2.15.2219.0). The facial temperature (before, after and during the test) was calculated from the mean values of the warmest points in the image, while the mean value of the observed body side represented the body temperature (before and after the test).

Statistical Analysis

Statistical analysis was performed using SAS/STAT software, version 9.4 of the SAS System for Windows (© 2002-2012 SAS Institute Inc). After participating in the SAB test, 2 dogs from the non-aggressive group were excluded from the analysis because they showed biting behavior, and there were 5 dogs from the aggressive group that did not show even a single attack. The final non-aggressive group included 13 dogs, while the aggressive group included 11 dogs. Normal distribution for the quantitative traits was determined using the Shapiro-Wilk test. All reported *P*-values that were <0.05 were considered statistically significant or tended to be significant if *P*-values were <0.10. Means with

TABLE 2 | Behavioral differences in the SAB test between dog groups.

Category	Behavior	Group	Mean ± SD	Value	*p*-value
Locomotion	Moving	12	112.08 ± 20.21 161.93 ± 29.79	−4.86^t	**<0.0001**
	Standing	12	148.68 ± 38.46 125.75 ± 22.45	1.74^t	0.10
	Sitting	12	34.08 ± 26.92 20.36 ± 16.31	1.47 ^{t}	0.16
	Lying down	12	26.35 ± 48.89 11.48 ± 19.63	−0.62^Z	0.54
Posture	High	12	71.19 ± 64.97 47.77 ± 64.10	0.89^t	0.39
	Neutral	12	198.40 ± 50.99 178.45 ± 67.63	0.82^t	0.42
	Low	12	49.86 ± 40.89 87.23 ± 41.99	−2.20^t	**0.04**
Aggression	Staring	12	0.00 ± 0.00 7.27 ± 4.77	−4.44^Z	**<0.0001**
	Short bark	12	1.92 ± 3.28 1.46 ± 1.63	−0.82^Z	0.41
	Rapid barking	12	4.34 ± 11.16 35.92 ± 37.99	−3.26^Z	**0.001**
	Growling/barking	12	0.85 ± 1.63 0.93 ± 1.41	−0.40^Z	0.69
Fear/stress	Fleeing/retreating	12	5.31 ± 5.23 2.18 ± 1.40	−1.34^Z	0.18
	Stretching leash	12	3.23 ± 3.88 1.09 ± 1.64	−1.28^Z	0.20
	Snout licking	12	15.00 ± 15.20 20.55 ± 13.90	−0.95^t	0.37
	Whining	12	5.69 ± 10.50 7.55 ± 6.95	−0.83^t	0.62
Interaction with human	Support seeking	12	1.84 ± 1.99 1.91 ± 1.51	−0.44^Z	0.66
	Cover seeking	12	0.31 ± 0.63 0.64 ± 0.67	−1.42^Z	0.16
	Owner/handler seeking	12	11.75 ± 17.24 2.46 ± 6.05	−1.65^Z	0.10
Other behaviors	Play	12	12.54 ± 21.66 3.40 ± 5.10	−0.67^Z	0.53
	Exploration	12	23.32 ± 20.32 10.87 ± 6.05	−1.28^Z	0.21
	Tail wagging	12	53.37 ± 39.08 150.05 ± 53.4	−5.11^t	**<0.0001**
	Left tail wagging	12	1.39 ± 7.26 13.18 ± 6.88	−4.06^t	**0.001**

Group 1 = non-aggressive dogs; group 2 = aggressive dogs; ^{t}t-value (t-test); ^{Z}Z-value (Mann-Whitney U test). Bolded values show significant associations.

standard deviations (SD) or percentages were calculated for descriptive statistics.

For behavioral analysis, due to low occurrence, the variables teeth baring ($n = 0$ occurrences) and yawning ($n = 3$ occurrences) were excluded, and the variables snapping and attacking, fleeing and retreating, growling, and snarling were combined into snapping/attacking, fleeing/retreating, and barking/ growling. For each variable, the sum of the occurrences collected during the subtests was used. The difference between groups in demographic variables, behavioral variables, and aggression and anxiety scores was examined. Independent samples *t*-test with the instruction PROC TTEST was used to compare normally distributed variables. Mann-Whitney U-test with the statement PROC NPAR1WAY was applied for variables that were not normally distributed.

Temperature change relative to baseline values was used for data analyzes. There were 18 (4.7%) missing values from images during the test due to technical problems. Physiological data were analyzed using the general linear model (GLM) procedure. For the three cardiovascular models (facial temperature, body temperature, and facial temperature during the test), the fixed effect of group ($n = 2$, aggressive and non-aggressive groups), coat color ($n = 4$; brown, black, tricolor, black-brown), side of measurement ($n = 2$; left and right; for the body temperature model only), and subtest ($n = 16$; for the facial temperature during the test model only) on surface temperature was tested. Models also included age, body weight, coat length, humidity, wind, and aggression and anxiety scores as covariates and dog as a repeated measure (for the facial temperature during test model only). For the neuroendocrine models, the fixed effect of group, time of sampling ($n = 3$; home, pre-test, post-test), and age, body weight, aggression score, and anxiety score as covariates were tested at CORT and SER. The dog was included as a repeated measure. When a significant effect was found, the LSMEANS and ESTIMATE statements were used to compare means and estimate contrast between factor levels. To find significant differences when more than two means were compared, a multiple post-*hoc* test Tukey-Kramer was used. Non-significant variables were eliminated and the final model consisted of significant effects only. The final models achieved R-squared values ranging from 0.23 to 0.27.

To test the association between behavioral and physiological variables within dog groups, Spearman's rank correlation was applied using the PROC CORR statement. For this analysis, in addition to behavioral and surface temperature variables, home values (home CORT and SER) and changes between pre- and post-test CORT and SER were used (CORT and SER change). Only strong correlations ($r \geq 0.7$) are presented in this manuscript.

RESULTS

The selected dogs were of similar age (aggressive dogs: $n = 11$ dogs; mean age: 20 ± 4.9 months; non-aggressive dogs: $n = 13$; mean age: 24 ± 7 months, $t = 1.59$, $p = 0.13$) and coat length (4.3 cm ± 0.9 vs. 6.4 cm ± 4; $t = 1.70$, $p = 0.1$), but aggressive dogs were heavier than non-aggressive dogs (33.6 kg ± 3.1 vs. 25.3 ± 9.3 kg; $t = -2.84$, $p = 0.01$). After data inspection, the two neutered dogs within the non-aggressive group did not stand out in their values for all physiological and behavioral parameters compared to the rest.

Behavioral Testing

Aggressive dogs had a higher aggression score (10.18 ± 6.31) than non-aggressive dogs (0.46 ± 0.66, Z = −4.20, $p < 0.0001$), but an indifferent anxiety score (aggressive dogs = 6.18 ± 2.71; non-aggressive dogs = 8.15 ± 4.81, Z = −0.84, $p = 0.40$). Individual aggressive dogs that snapped or attacked 3 to 26 times per test (mean: 14 ± 6.8) were more likely to show lower body posture, more movement, staring, snapping/attacking, rapid barking, tail wagging, and left tail wagging than non-aggressive dogs (**Table 2**).

Measurement of the Salivary CORT and SER

Dog groups did not differ in CORT or SER, but timing of sampling influenced CORT (**Table 3**), with CORT tending to be lower at home than before the test ($p = 0.06$). As shown in **Table 3**, the covariate anxiety score was significant for CORT and SER, while the aggression score was significant for SER. Dogs with higher anxiety levels had higher CORT and SER, but those with higher aggression levels had lower SER.

Surface Temperature Measurements

Aggressive dogs (Δ = 1.81 °C, LSMEANS = 4.19) had a significantly greater change in facial temperature during the test than non-aggressive dogs (Δ = 0.98 °C, LSMEANS = −0.03, F = 57.75, $p < 0.0001$), but similar facial changes (non-aggressive dogs: LSMEANS = 1.52, aggressive dogs: LSMEANS = 0.03, F = 0.30, $p = 0.59$) and body surface temperature (non-aggressive dogs: LSMEANS = 0.71, aggressive dogs: LSMEANS = 1.19, F = 0.01, $p = 0.94$). The change in facial surface temperature during the test was influenced by three variables (**Table 4**). Longer coat, lower humidity, and stronger wind increased or tended to increase temperature. Although one effect of the subtest showed a trend, there were no significant changes between subtests (**Supplementary Table 2**).

Relationship Between Behavioral and Physiological Measures

Several highly significant correlations were found within each dog group (**Figure 2**). In the aggressive group, aggression score correlated positively with moving, staring, snapping/attacking, rapid barking, and left tail wagging. Rapid barking correlated positively with moving, staring, and high posture. Staring correlated positively with rapid barking and negatively with snout licking and cover seeking. Tail wagging was positively correlated with low body posture. Left tail wag (side wag bias) was positively related to aggression score, moving, and high posture and negatively related to neutral posture. High posture was also negatively correlated with neutral posture and cover seeking.

In the non-aggressive group, aggression score was positively correlated with low posture, growling/barking, and higher

TABLE 3 | Effects of variables tested on CORT and SER.

	CORT			SER		
Continuous variable	**Estimate**	**F**	***p***	**Estimate**	**F**	***p***
Age	0.03	0.56	0.46	0.03	0.56	0.46
Weight	−0.05	2.73	0.10	0.09	0.09	0.77
Aggression score	0.01	0.05	0.82	−1.00	−3.13	**0.003**
Anxiety score	0.12	2.37	**0.02**	1.29	2.62	**0.01**
Level variable	**LSMEANS (ng/mL)**	**F**	**p**	**LSMEANS (ng/mL)**	**F**	**p**
GroupAggressive dogs	2.62	0.10	0.76	24.39	0.10	0.90
Non-aggressive dogs	2.83			25.24		
TimeHome	2.08[a]	2.54	**0.09**	27.05	0.32	0.73
Pre-test	3.29[b]			23.94		
Post-test	2.78[ab]			23.47		

[a,b]Values with different superscripts differ significantly.
Bolded values show significant associations.

TABLE 4 | Effects of continuous variables tested on changes (Δ) in surface temperature.

Variable	Δ body temperature			Δ facial temperature			Δ facial temperature during testing		
	Estimate	**F**	***p***	**Estimate**	**F**	***p***	**Estimate**	**F**	***p***
Age	−0.28	2.04	0.18	−0.06	0.49	0.50	−0.01	0.07	0.79
Weight	−0.03	0.70	0.84	0.08	1.27	0.28	0.00	0.07	0.79
Coat length	−0.08	0.04	0.84	0.14	0.55	0.47	0.11	8.37	**0.004**
Humidity	0.16	2.12	0.20	0.07	2.23	0.16	−0.09	106.70	**<0.0001**
Wind	0.28	0.51	0.49	0.08	0.23	0.64	0.06	3.34	**0.07**
Aggression score	−0.22	0.67	0.40	0.02	0.04	0.85	0.00	0.00	0.98
Anxiety score	0.06	0.05	0.83	−0.17	2.13	0.17	−0.07	0.22	0.64

Bolded values show significant associations.

home CORT. Home CORT also correlated positively with growling/barking. Anxiety score correlated positively with stretching the leash. Low posture correlated positively with growling/barking, fleeing/retreating, and leash stretching. Neutral posture correlated negatively with snout licking and left tail wagging. SER change correlated positively with tail wagging.

Combining behavioral, neuroendocrine, and cardiovascular data, the aggressive dogs in our study were characterized by a lower posture with ears held back. They stared, snapped, or attacked, barked rapidly, and wagged their tails frequently, especially on the left side. The physiological profile included increased facial surface temperature and lower SER.

DISCUSSION

In this study, simultaneous and non-invasive observation of behavioral, cardiovascular, and neuroendocrine changes during aggressive reactivity provided a profile of an aggressive dog that has never been presented before. Although we cannot fully support our hypothesis of neuroendocrine activation, as we found no difference in the serotonergic system and hypothalamic-pituitary-adrenal (HPA) axis in aggressive dogs compared to non-aggressive dogs, our results suggest that higher levels of aggression are associated with lower levels of salivary SER. We confirmed cardiovascular activation, but the finding of increased facial temperature in aggressive dogs is contrary to our expectations. Our results also confirmed the importance of measuring tail wagging and side wagging in dogs when faced with emotional challenges.

Based on owner-reported history of aggression and display of biting behavior in a standardized dog behavior test, our dogs were successfully divided into the aggressive and non-aggressive groups. The phenotypic description of aggressive dogs with lower posture, ears held back, increased staring, snapping, attacking, and rapid barking was consistent with previous observations (34, 47). In addition to these known behaviors, we also observed and described for the first time an increased frequency of tail wagging and more frequent wagging to the left during aggression. Tail wagging is mainly reported in association with positive affective states in dogs (48, 49). However, Quaranta et al. (50) argued that dogs show asymmetric tail wagging in response to stimuli with different emotional valence. This asymmetry is due

A Aggressive group

Aggression score	1											
Moving	.83	1										
High posture			1									
Low posture				1								
Neutral posture			-.78		1							
Staring	.74					1						
Snapping/attacking	.76						1					
Rapid barking	.92	.72	.72			.88		1				
Snout licking						-.76			1			
Cover seeking			-.74			-.81				1		
Tail wagging				.77							1	
Side wag bias	.72	.72	.78		-.81							1

B Non-aggressive group

Aggression score	1											
Anxiety score		1										
Neutral posture			1									
Low posture	.71			1								
Growling/barking	.74	.70		.74	1							
Fleeing/retreating				.75		1						
Stretching leash		.78		.73			1					
Snout licking			-.79					1				
Tail wagging									1			
Side wag bias			-.76							1		
Home CORT	.75				.73						1	
SER change									.86			1

FIGURE 2 | Significant correlations between aggression and anxiety score, behavioral and physiological variables (when r ≥ 0.7) within **(A)** the aggressive group and **(B)** the aggressive group of dogs.

to differential activation of left and right brain structures (51). A higher amplitude of tail wagging on the right side has been found for stimuli that dogs perceive as positive, while the left side is perceived as negative (50). Measuring the frequency of tail wagging on each side and finding a high correlation of the amplitude of tail wagging to the left side with aggression level and aggression-related behaviors may indicate that left tail wagging is associated with aggressive behaviors. Because left tail wagging results from right hemisphere activation (51), our findings are consistent with other canine studies (52) and several other animal studies (53) that indicate right hemisphere specialization for the expression of intense emotions, including hostility and aggression. Further behavioral observations show that dogs had similarly low levels of anxiety and indifferent anxiety-related behavior whether or not they were characterized as aggressive. This, coupled with the fact that anxiety and aggression share similar physiological reactivity (32), leads us to believe that the physiological changes observed during the test are related only to aggression-related behaviors. We found that some of these behaviors, particularly aggressive threatening behaviors (e.g., growling, barking), were associated with CORT collected in the home neutral environment, but surprisingly only in dogs that do not normally respond aggressively (i.e., non-aggressive dogs).

To find an increase in pre-test CORT values compared to baseline values prior to test participation, albeit with a weak trend, could indicate emotional arousal rather than emotional valence according to Lewandowski et al. (54). Based on this and the evidence that physiology can be altered simply due to arriving in a new situation and meeting new people (55) or anticipation of an activity (56), we consider it less likely that the pretest release of CORT was triggered by transport-induced stress. Assuming that SER responds rapidly to environmental stimuli (24) and that no changes were found between home and pre-test SER, this further suggests that the factors that altered pre-test CORT did not represent a stressful experience for the dogs.

During testing, our results found similar activation of the stress and serotonergic systems in the two groups of dogs, which is not what would be expected based on the nature of the stimuli presented in the behavioral test (57) and based on previous research. We expected aggressive dogs to show higher HPA axis activity based on documentation in humans (58) or in dogs with a history of aggression (9) and during displays of aggression between dogs (59). Next, we expected these dogs to also have a lower SER because a reduced SER produces a generalized state of hyperirritability and lowers the threshold at which humans and animals respond to provocative stimuli (60). Our results were distinctive due to methodological differences and difficult to compare with other studies. Our dogs were tested during real-time aggression, whereas previous studies compared SER and CORT in dogs with or without owner-reported aggression history. Due to the fact that aggressive dogs are under the influence of an emotional attachment to their owner/handler (61), the owner/handler could represent a stress buffer for our dogs, influencing the dog's behavior and physiology, as previously observed for stimuli with a threatening approach (12), potentially masking the physiological changes that resulted from the aggression.

Because only a single bite attempt during the test was sufficient to classify the dog as aggressive, some dogs exhibited biting behavior on infrequent occasions, while some others attempted to bite up to 26 times during the test. Thus, the variability of aggression within the aggressive group was high. Highly aggressive dogs were found to have a lower SER, which is consistent with studies on dogs with a history of aggression (6, 8, 9). We find this result valid since it is known that SER plays a role in the neural control of aggression as an inhibitory regulator of aggressive reactivity (24) and dogs with a low SER have been associated with impaired impulse control (62). This phenomenon has been described as the serotonin deficiency hypothesis of aggression, demonstrating the inverse relationship between SER and aggression in humans (63) and non-human animals (64). Based on our results, it is reasonable to assume that neuromodulation, expressed as a lower SER, is evident only in dogs that exhibit high levels of aggressive behavior.

In addition to neuroendocrine activation, activation of the sympathetic nervous system leading to lower surface temperature has been documented in several animal studies when animals were presented with various aversive situations [monkeys: (18); dogs: (15, 17); rabbits: (19); pigs: (20)]. To our knowledge, only two studies examined surface temperature in an aggressive context [pigs: (20); dogs: (21)]. When comparing temperature change relative to baseline, Rigterink et al. (21) found an increase in eye temperature in both aggressive and non-aggressive dogs, whereas we found no such changes in facial or body surface temperature, regardless of aggression group. However, we believe that the discrepancy between the results is due to the fact that their aggressive group consisted of only 27% of dogs that showed aggressive reactivity during interaction with an unfamiliar person, whereas in our study all such dogs were included and their temperature changes were observed on a smaller area that is assumed to be highly reactive.

However, we observed an increase in facial surface temperature during an actual act of aggression in aggressive dogs, suggesting that aggression activates cardiovascular activation in real time, but not the stress axis, measured as increased salivary CORT. Assuming that eye temperature increases during both negative stressful experiences (15) and positive experiences in dogs of both sexes (49), the change in surface temperature could reflect emotional arousal but not necessarily emotional valence. This has also been suggested in pigs, where Boileu et al. (20) reported a decrease in dorsal surface temperature in pigs during social aggression in both winning and losing individuals. Ward et al. (65) reported an increase in aggressive behavior in males exposed to exercise-induced arousal, similar to what we found.

Our results further suggest that thermal images taken during the test may be considered a better indicator of cardiovascular activation after an aggressive response than the change in temperature before and after the test. This assumption should be taken with some caution, as an increase in surface temperature could be influenced by physical activity. Our aggressive dogs moved significantly more than non-aggressive dogs and exercise resulting in heat being dissipated through skeletal muscle, could lead to an increase in surface temperature (66). In addition, our study is the first field study of its kind to examine aggressive dogs outdoors, but this can be problematic for optimal thermal imaging data collection. These data are typically conducted indoors or in a controlled environment with constant temperature and humidity (11, 15, 19, 21). Our observation revealed that not only humidity and wind act as potential confounders on surface temperature, but also coat length.

In light of our findings, we believe that future studies of aggressive behavior in dogs should address certain methodological improvements. First, rather than looking for a specific phenotype, 'it would be preferable touse a dog as its own control (67), which could overcome the problems of inter-subject variability. Second, participants in our study found the method of saliva collection challenging, so we believe that an alternative method for easier and safer saliva collection, such as a collection tube or cotton head on a plastic handle (13), should be used, especially if a collecting individual is inexperienced and if the dogs involved are aggressive.

CONCLUSIONS

Although our study faces numerous methodological challenges, it represents an important step in simultaneously investigating animal behavioral and physiological responses in the field and in real time. Our work provides the first evidence that aggressive dogs can be characterized by serotonergic, measured as salivary SER, and cardiovascular features, measured as increased facial temperature, during an actual aggressive act. The discovery of novel aggression-related behaviors such as tail wagging and left tail wagging opens a new avenue for the study of lateralization in the context of aggression.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The animal study was reviewed and approved by Administration of the Republic of Slovenia for Food Safety, Veterinary Sector and Plant Protection. Written informed consent was obtained from the owners for the participation of their animals in this study.

AUTHOR CONTRIBUTIONS

EG and MZ: conceptualization, methodology, formal analysis, and writing—review and editing. EG: data collection, data curation, and writing—original draft preparation. MZ: supervision. Both authors approved the submitted version of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fvets.2021.683858/full#supplementary-material

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Supplementary Material

1 Supplementary Figures and Tables

Supplementary Table S1. Descriptions of 16 Socially Acceptable Behavior subtests (33).

Subtest	Description
1	The dog is approached by one tester and petted with an artificial hand
2	The dog is exposed to an unfamiliar visual stimuli (a blanked is pulled up and down)
3	The dog is exposed to an unfamiliar visual stimuli (sudden appearance of a cat on a sledge)
4	The dog is exposed to an unfamiliar sound (sudden activation of a horn)
5	The dog is exposed to an unfamiliar sound (sudden rattle of metal cans)
6	The dog is slowly approached and surrounded by three testers
7	The dog is rapidly approached and surrounded by three testers
8	The dog is approached by one tester with a dummy dog
9	The dog is slowly approached by one tester and petted using an artificial hand
10	The dog is exposed to an unfamiliar sound (a bell is rang in front of the dog)
11	The dog is exposed to an unfamiliar visual stimuli (an umbrella is rapidly opened and closed in front of the dog)
12	The dog is exposed to an unfamiliar visual stimuli (a life-sized doll, standing on top of a sledge is pulled in front of the dog)
13	The dog is approached by one tester and petted with a doll fixed on a pole
14	The dog is approached by one tester staring.
15	The dog is approached by the same tester as in subtest 14 and petted with an artificial hand
16	The dog is approached by the owner or handler and petted with a doll

Supplementary Material

Supplementary Table S2. Effects of variables tested on changes (Δ) in surface temperature.

		Δ body temperature			Δ facial temperature			Δ facial temperature during testing		
Variable	Level	LSMEANS	F	p	LSMEANS	F	p	LSMEANS	F	p
Coat color	Brown	1.67	3.03	0.11	0.98	0.47	0.50	2.47	1.14	0.38
	Black	1.38			0.67			1.55		
	Tricolor	2.10			0.30			2.21		
	Black -brown	-2.34			0.21			2.10		
Side	Right	-0.64	0.73	0.41	-	-	-	-	-	-
	Left	2.00			-	-	-	-	-	-
Subtest	1	-	-	-	-	-	-	1.35	1.63	0.06
	2	-	-	-	-	-	-	1.60		
	3	-	-	-	-	-	-	1.45		
	4	-	-	-	-	-	-	1.72		
	5	-	-	-	-	-	-	1.48		
	6	-	-	-	-	-	-	1.87		
	7	-	-	-	-	-	-	1.94		
	8	-	-	-	-	-	-	1.92		
	9	-	-	-	-	-	-	2.37		
	10	-	-	-	-	-	-	2.79		
	11	-	-	-	-	-	-	2.58		
	12	-	-	-	-	-	-	2.65		
	13	-	-	-	-	-	-	2.26		
	14	-	-	-	-	-	-	2.11		
	15	-	-	-	-	-	-	2.62		
	16	-	-	-	-	-	-	2.59		

3 DISCUSSION AND CONCLUSIONS

3.1 DISCUSSION

Previous research has revealed several methodological limitations and knowledge gaps regarding factors involved in dog aggression. In this thesis, we sought to build a more comprehensive picture of the mechanisms involved in dog aggression in a multidisciplinary manner, by using a combination of different methodological approaches in four separate studies.

3.1.1 Contexts, dogs' and dog bite victims' characteristics

In the first study, we confirmed our hypothesis that examining dog bites that are not limited to a prior dog-human interaction, reveals a greater number of contexts in which dog bites commonly occur. In contrast to previous findings, where contact activities were most common (Gautret et al., 2013; Sarcey et al., 2017; Oxley et al., 2018), our results showed that half of the described biting incidents occurred without prior interaction and often included bites during fast movements around the dog, while getting into close proximity to the dog and during incidents described as without a reason. Before the incidents, victims often reported they were walking towards or past a dog, or making fast movements by running or riding a bike on the street. This type of human behaviour, especially at the location the dogs perceive as territory, can lead to territorial aggression (Chávez and Opazo, 2012; Owczarczak-Garstecka et al., 2018a), even without actually presenting a threat. This is particularly common when it involves a person with whom the dog does not live with (Kuhne et al., 2014; Tuber, et al., 1996), which was also confirmed in our study. These bites, during which the victim unintentionally or passively interacted with the dog, involved purebred dogs with a history of aggression. They resulted mainly in one bite and occurred in a public space in the vicinity of an acquainted or unknown dog's home. The finding that biting incidents without prior interaction are as important and as frequent as bites with prior interaction, suggests a more complex contextual aspect of dog aggression than previously reported.

Other findings of this study are consistent with previous research. As reported by Bregman and Slavinski (2012) and Touré et al. (2015), the majority of bite victims were bitten when they were children or teenagers, under 19 years of age. Despite the fact that males are more likely to be bitten than females (Súilleabháin, 2015; Westgarth et al., 2018), we were unable to confirm this in our study due to the overrepresentation of female responders. Regarding the location of biting incidents, as previously shown (Babazadeh et al., 2016; Rosado et al., 2009), low-populated areas appeared to be at higher risk, probably due to better control of dogs in urban areas with more people and traffic (Rosado et al., 2009). Next, as reported before, the dogs involved were primarily adult males, large in size, and originated from a breeder or known person (Oxley et al., 2018; Sarcey et al., 2017). The majority of our dogs were unnutered (Patronek et al., 2013; Shuler et al., 2008) and socialized as puppies, which does not appear to reduce aggression (Wormald et al., 2016). Similar to Gershman et al. (1994), living exclusively outdoors and being chained, appear to be associated with display of aggression. As there were a large number of different breeds seen in our study, this suggests that there is a high variation among breeds involved in human-directed aggressive behaviour (Duffy et al., 2008), but German Shepherds again appear to be the most commonly involved breed (Oxley et al., 2018; Sarcey et al., 2017). Finnaly, despite the inconsistent results regarding the association between biting incidents and dog's history of aggression (Oxley et al., 2018; Sarcey et al., 2017), we found that most biting dogs have reports of previous biting behaviour. As it appears that any dog is capable of exhibiting biting behaviour in specific context (Bradshaw et al., 2009), even if it has never bitten before (De Keuster et al., 2006).

Regarding the data collection, it is important to note, that this was a retrospective study and a lot of responders described events that occurred when they were children. That puts in question the validity of responses due to questionable recall accuracy and difficulty to remember details of the past event (Hipp et al., 2020), especially since we did not control for the time passed between the present and the event of interest. On this note, also the presented statistical data regarding breeds of dogs have to be interpreted with caution, as it may differ from the past data at the time of the attack. In addition, as most responders were children at the time of the attack, it is possible they did not have enough knowledge regarding dog behaviour and potentially misinterpreted the situation. Despite that, our results show a more complex contextual aspect of dog bites and shed a new light on this old problem, especially regarding the prevention. Most commonly used preventive methods, such as recognition of warning signs, is not applicable in bites without prior interaction. To include preventions of all bites, other approaches focusing on proper education of dog owners and parents regarding the supervision of dogs and children, especially in situations that present a risk factor, should be highlighted in the future.

3.1.2 Psychosocial effects

By using a combination of methodological approaches, knowledge regarding psychosocial factors was also upgraded. We predicted several dog and owner personality traits, as well as owner attachment style to be associated with dog aggression. In terms of dog personality, we were able to partially confirm our hypotheses, as sociability was the only trait associated with aggression. Group of dogs categorized as aggressive toward humans generally had lower scores for trait sociability than non-aggressive dogs. In addition, for less sociable dogs, more frequent display of aggression towards strangers was reported by the owners. Our results deriving from the combination of behavioural observations and questionnaire data were consisted with previous questionnaire-based reports, linking low sociability with stranger- and child-directed aggression (Kaneko et al., 2013). Sociability seems to be the trait most strongly associated with aggression, because highly sociable dogs have better social control from meeting new people, and being in new environments. Therefore, such situation does not cause higher stress levels that can potentially trigger aggression (Yang et al., 2017).

Similarly, while observing owners' personality traits, we partially confirmed our hypotheses, as only owners with higher scores for neuroticism were associated with dogs aggressive towards strangers and other dogs. Positive associations between owners' neuroticism and behavioural problems in their pets have been found in dogs (Podberscek and Serpell, 1997) and cats (Finka et al., 2019). There are several possible explanations for why neurotic owners tend to affect social behaviour of their dogs. First, neurotic owners have higher stress and cortisol levels (Schöberl et al., 2012) and tend to display unpredictable styles of caretaking, are more hostile and less warm, possibly decreasing social control and increasing stress levels of their pet (Finka et al., 2019). Second, more neurotic individuals generally tend to choose dog breeds that are considered more aggressive (Egan and MacKenzie, 2012). Overall, it appears that neurotic owners have a particular physiological and behavioural characterization that affects their dogs' social behaviour.

Another interesting finding related to owner personality traits was the fact that in the non-aggressive dog group, more extraverted owners had dogs with lower scores for chasing behaviour. Despite not necessary being directly associated with aggression, it is important to address this behaviour because chasing other, usually smaller animals, is a common unwanted and potentially dangerous behaviour in dogs (Zamora-Nasca et al., 2021). The explanation for the association between extroversion and chasing may be that more extroverted people enjoy being in the company of other people and often participate in various activities and social events (Lucas and Diener, 2001), which socializes their dogs and familiarizes them with strangers and other animals.

For the last parameter observed, attachment, we were the first to confirm a relationship between owners' attachment style to their dog and dog aggression. Although we found that both insecure attachment styles play a role in dog aggression, the direction of the association with aggression was consistent only with our predictions regarding the avoidant and not anxious attachment style. In our study, owners with higher scores for avoidant attachment had dogs with higher scores for owner-directed aggression. More avoidant individuals are known for distancing themselves from others and not providing enough intimate contact, affection and availability (Hazan and Shaver, 1987). Because the owner presents a secure base for their pet (Finka et al., 2019), especially during threatening situations (Rehn et al., 2017), the dogs of owners with this type of attachment may perceive the lack of a secure base as stressful and fear-provoking, possibly leading to often observed fear-related aggression (Flint et al., 2017). While for anxious attachment, contrary to our predictions, owners with lower scores were associated with dogs scoring high for stranger-directed aggression. Our findings are in contrast with reports in humans, in which child aggression was associated with anxious mother-infant attachment (Amani, 2016). It appears that behaviour associated with anxious attachment, such as clinginess, control, closeness and support seeking (Shaver and Mikulincer, 2002), do not contribute to the loss of secure base (Whipple et al., 2011) and do not play a role dog aggression. We can surmise that dogs of owners with anxious attachment style are accustomed to proximity and close relationship with people, and are therefore comfortable and calm in the company of strangers, reducing the likelihood of aggression. For better understanding of attachment as a whole, further studies should also use approaches that include assessment of both, insecure and secure attachment styles, as well as a larger sample size.

Nevertheless, the knowledge regarding the parameters linked to aggression in this study may be important for both, the scientific community and the general public. The parameters (e.g., sociability, neuroticism) are easily observable by dog owners and better understanding of importance of certain traits could help owners identify potential risk factors for aggression, take appropriate actions early and improve the relationship with their dog.

3.1.3 Cognitive effects

For the first time, different aspects of inhibitory control were assessed in relation to aggression. Predictions in the third study were partially confirmed, as only self-control, but not cognitive inhibition, was associated with dogs exhibiting biting behaviour during behavioural testing. Consistent with research findings in humans (Herndon et al., 2015) and rats (Van den Bergh et al., 2006), we found that dogs with the most severe display of aggression showed impairments in self-control, measured as poor performance in the delay of gratification test. Self-control is considered as one of the neuropsychological concepts of executive control (Séguin and Zelazo, 2005), which plays a role in the self-regulation of actions and emotions. Another mechanism mediated by executive control (Reynolds et al., 2019), often described in the context of dog aggression (Amat et al., 2009) is impulsivity. Previous research has suggested that delay of gratification presents an index of impulsive behaviour and that a lack of self-control can also be described as impulsivity (Wright et al., 2011). Impulsive dogs have been categorized as showing no or fewer warning signs before aggression (Fatjó et al., 2005). Based on this finding, we found that our dogs with poorer performance on the delay of gratification test were impulsive, as they also displayed aggressive biting behaviour. Furthermore, our results are consistent with Wright et al. (2011), who reported that dogs with higher owner-assessed trait impulsivity were more likely to be aggressive. Despite the methodological differences, the results are highly comparable, since it was assumed that subjective owner reports regarding impulsivity are consistent with performance during cognitive testing (Wright et al., 2011). In summary, the relationship between impulsivity and aggression found in our study appears to be consistent across mammals, since it reflects the findings in rats (Ferrari et al., 2005), humans (Blair, 2016) and non-human primates (Ferrari et al., 2005). However, it is important to note that the specific training and lifestyle of police dogs included in our study may influence their performance in the tests. In addition, low variation in the delay of gratification results could potentially limit the power of the results and thus our findings have to be interpreted with cation. To avoid that, further studies assessing self-control should consider including larger sample size, dogs with more similar behavioural and training background and larger number of cognitive tests per aspect.

In contrast, we found no association between impairments in cognitive inhibition, measured as poor performance on the reversal learning test, and aggression, as is the case in humans (Mitchell et al. 2006). However, direct comparison of our results with human literature is somewhat problematic. The first problem presents the human population included in these studies. Reversal learning is often studied in humans with psychiatric disorders associated with increased aggression, such as psychopathy, attention deficits, and hyperactivity disorder (Turgay, 2004), making comparison with dogs and interpretation of the results very hard. The second problem is frustration, which is the main factor contributing to aggression in people with psychiatric disorders (Blair, 2010). This makes comparisons with dogs very difficult, as in dogs frustration has not been studied as a mechanism of aggression, but mostly in the relation to inaccessibility, decrease in value or absence of food (Jakovcevic et al., 2013; Bremhorst et al., 2019; Dzik et al., 2019).

The lack of association between performance in both, reversal learning and delay of gratification with aggression, supports the context specificity of inhibitory control measures, proposed in previous dog studies (Bray et al., 2014; Brucks et al., 2017; Vernouillet et al., 2018). It appears that task demands, described as the set of skills the dogs must possess to successfully perform in the test (Bray et al., 2014; Vernouillet et al., 2018) may account for the lack of association between the tests. In conclusion, our findings suggest that particular behaviour, such as aggression, may be associated with limited aspects of inhibitory control. Dogs in our study displayed better inhibitory control in both tests, compared to previous research on pet dogs (Brucks et al., 2017), highlighting the importance of any kind of behavioural training for better cognitive performance. Also, the identification of impulse behaviour as a potential mechanism of aggression, may be useful for early recognition of unwanted behaviours and early application of appropriate preventive measures.

3.1.4 Physiological effects

In the fourth study, in which we examined neuroendocrine and cardiovascular parameters measured simultaneously and non-invasively during aggression, we could only partially confirm our predictions. As expected, we found lower salivary serotonin concentration (SER) in highly aggressive dogs. This is consistent with previous studies reporting lower plasma and serum SER in dogs with owner-reported history of aggression (Çakiroglu et al., 2007; Rosado et al., 2010; León et al., 2012). In humans (Duke et al., 2013) and non-human animals (Ferrari et al., 2005), this occurrence of inverse relationship between SER and display of aggression, has been referred to as the serotonin deficiency hypothesis. This phenomenon is evident in dogs, since dogs with lower SER are reported to have impaired impulse control (Reisner et al., 1996) and SER is known to be a neural regulator of aggression that acts as an inhibitor of aggressive reactivity (Summers and Winberg, 2004). Based on our results it appears that neuroendocrine activation, measured as decreased SER, is only evident in dogs during display of severe aggression.

In contrast, we found no association between neuroendocrine activation, measured as increased salivary cortisol concentration (CORT) and aggression in real-time. This is in contrast to reports in humans (Haller et al., 2005) and dogs with an owner-reported history of aggression (Rosado et al., 2010). Nevertheless, our results may be difficult to compare due to methodological differences. CORT was measured during real-time aggression in our dogs, whereas other dog studies compared CORT of dogs with or without owner-reported past aggressive behaviour. Furthermore, we believe that physiological changes may be masked by the effects of the owner or handler during testing and saliva collection, as the presence of a person with an emotional attachment to the dogs can influence the behaviour and physiology during aversive situations (Gácsi et al., 2013). However, we found that aggressive threatening behaviours during the test (e.g., growling, barking) was associated with higher CORT in the home environment, but only in a group of dogs categorized as non-aggressive. Another finding regarding CORT included higher pre-test CORT compared to CORT in the home environment. This can be explained by the fact CORT can indicate emotional arousal, and not necessarily emotional valence (Lewandowski et al., 2014) and can be influenced by the anticipation of an activity (Horváth et al., 2008), arrival to a new place and meeting of new people (Ng et al., 2014).

For the third physiological parameter observed, skin surface temperature, we were unable to confirm our initial hypotheses. Based on several animal studies including dogs (Part et al., 2014; Travain et al., 2015), monkeys (Kuraoka and Nakamura, 2011), rabbits (Ludwig et al., 2007) and pigs (Boileau et al., 2019), which reported decreased skin temperature during aversive situations, we predicted decrease in facial and body skin temperature during dog aggression in real-time. In contrast, we found no changes in post-test compared to pre-test values, but we did observe increase in facial temperature in aggressive dogs during testing. When comparing our results to a previous study that examined surface temperature in dogs during aggression (Rigterink et al., 2018), some similarities can be seen. Rigterink et al. (2018) reported an increased eye temperature in the aggressive group, but also in the non-aggressive dogs during veterinary visit. Other studies have also shown that surface temperature of dogs increases in both negative situations (Travain et al., 2015), and positive experiences (Travain et al., 2016) or decreases in both winning and losing pigs during social aggression (Boileau et al., 2019). Therefore it can be suggested that changes in surface temperature may reflect emotional arousal, and not necessarily emotional valence. Our further results show that thermal images taken during the aggression test are a better indicator of cardiovascular changes due to aggression, compared to observation of temperature change before and after the test. This result should be viewed with caution, as aggressive dogs in our study moved significantly more than non-aggressive dogs during the test, and the increase in surface temperature may be influenced by exercise (Cilulko et al., 2013). Another limitation presents the grouping selection. As all dogs in the aggressive group were police dogs, the physiological activation and behavioural reactions may be specific for police dogs and not aggressive dogs in general.

Independent of the physiological observations, in this study we identified and described a new behaviour associated with aggression in addition to the usual aggression-related behaviours (e.g., snapping, attacking) (Netto and Planta, 1997; Haverbeke et al., 2009). For the first time, we observed an increased frequency of tail wagging and left tail wagging bias in aggressive dogs. Although tail wagging has been described mainly in relation to positive affective states in dogs (McGowan et al., 2014; Travain et al., 2016), Quaranta et al. (2007) reported that asymmetric tail wagging can be observed during stimuli with different emotional valence. Left tail wagging bias has been observed during stimuli the dog perceived as negative, and right tail wagging bias during stimuli that were perceived as positive (Quaranta et al., 2007). This asymmetry arises from different activation of right and left brain hemisphere (Buxton and Goodman, 1967). Because left tail wagging occurs during right hemisphere activation (Buxton and Goodman, 1967), our finding further indicates the right hemisphere is specialized for expression of intense emotions, as previously shown in dogs (Siniscalchi et al., 2019) and other animals (Rogers, 2010). Despite some methodological limitations, our study highlights the benefits and problems of real-time physiological and behavioural observations in the field and can be used as a stepping stone for further research.

3.2 CONCLUSIONS

In this thesis, four separate studies investigating contextual, psychosocial, cognitive and physiological aspects of dog aggression were conducted and several novel findings were reported (Figure 1). The following conclusions can be drawn from our work:

- When considering the contexts of dog bites, we found that during only half of the reported bites the biting victim willingly interacted with the dog. During the other half, the victim had no intention of interacting with the biting dog. Bites during fast movements around the dog, bites occurring while passively being in a close proximity to the dog and bites without a known reason were the three novel contexts that appear to be common in bites without prior interaction with the dog.

- In terms of owner and dog personality traits, neuroticism and sociability, respectively, are the two traits associated with human-directed dog aggression. The novel finding of this study is the association between insecure owner-dog attachment styles and human-directed dog aggression. Owners with high scores for avoidant attachment had dogs exhibiting owner-directed aggression and those with low scores for anxious attachment had dogs exhibiting stranger-directed aggression. It appears that both the dog and owner personality profiles play a role in the occurrence of dog aggression.

- For the first time, several aspects of inhibitory control were examined in relation to dog aggression. Impaired self-control, measured as poor performance in the delay of gratification was associated with aggressive biting behaviour. There was no association between cognitive inhibition, measured as performance on reversal learning, and aggression. It appears that behaviour such as aggression is associated with limited aspects of inhibitory control.

- During display of real-time aggression, simultaneous investigation of dog behavioural and physiological responses in the field revealed serotonergic activation, measured as decreased salivary SER, as well as cardiovascular activation, measured as increased facial surface temperature. In addition, a novel aggression-related lateralized behaviour, seen as more frequent tail wagging and left tail wagging bias, were observed and described for the first time in our study.

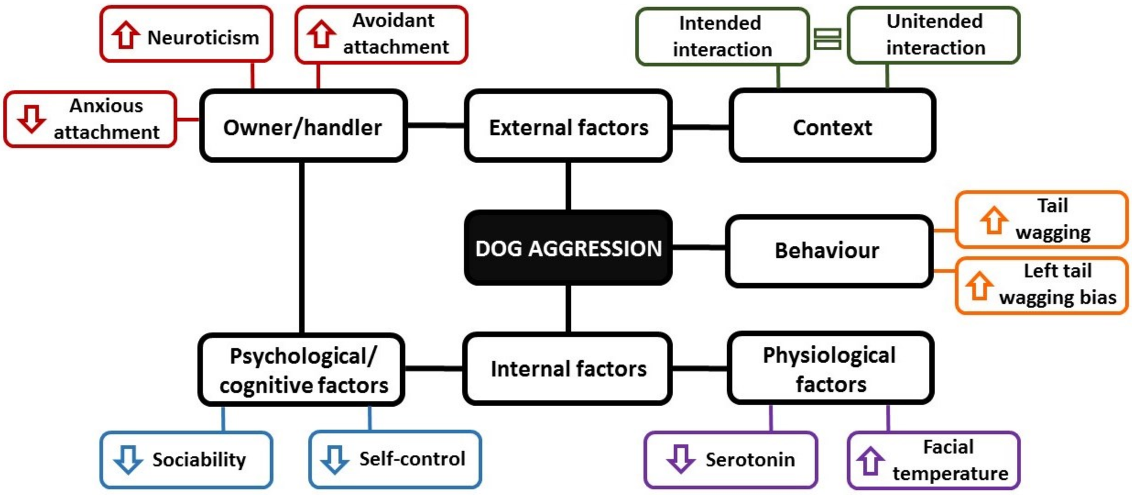

Figure 1: Schematic representation of the main findings

4 SUMMARY (POVZETEK)

4.1 SUMMARY

Aggression is part of normal behaviour of dogs and can be categorized as aggressive threatening behaviour (e.g., growling, baring teeth) or aggressive biting behaviour (e.g., snapping, attacking) (Netto and Planta, 1997). However, when aggression is directed toward owners or other people, it is considered one of the most unwanted and dangerous behaviours in dogs. Despite the fact that a considerable number of people, especially children (Súilleabháin, 2015), are bitten by a dog, and that aggression is a common reason for dogs to be abandoned, euthanized or relinquished to animal shelters (Salman et al., 2000; Diesel et al., 2008), there are still significant knowledge gaps regarding dog aggression. The aim of this thesis was to address these gaps by conducting four separate studies, each investigating a particular aspect of this behaviour. In order to assess aggression from different perspectives, we began with external factors, looking at the environment and interaction with humans, then moved to the psychosocial and cognitive factors, and concluded with the physiological factors.

Our first study of contexts and interactions with humans focused exclusively on aggressive biting behaviour. Previous research on dog bites reported on the characteristics of the dogs involved, such as breed, age and sex, and the post bite implications for the dog (Salman et al., 2000; Diesel et al., 2008; Oxley et al., 2018). They often described the consequences and characteristics of victims, for example their age and gender, the location and severity of the bite (Rosado et al., 2009; Horisberger et al., 2004; Oxley et al., 2018). Authors reported that most bites occur during the direct interaction between humans and dogs, for example, during petting or play (Rosado et al., 2009; Horisberger et al., 2004; Oxley et al., 2018) and on private property (Oxley et al., 2018). However, most studies lack a thorough assessment of dog bites, particularly a detailed description of the circumstances surrounding the dog biting incident. We hypothesized that a thorough investigation of dog bites, not limited to direct interactions with the dog, will lead to a greater number of dog biting contexts than previously reported (Oxley et al., 2018).

To obtain this information, an online questionnaire with 29 questions was used. Six open-ended and 23 closed-ended questions were divided into four sections. The first and the second one touched on victims' and biting dogs' demographics. The third section focused on a precise description of the biting incident, dogs' and victims' behaviour and location, and the last section was about post-bite implications for the dog. The results of the first two sections were consistent with previous research. Most individuals were bitten when they were children or adolescents (Bregman and Slavinski, 2012; Touré et al., 2015). The dogs involved were mainly large adult males that were known to the victim and came from a breeder or known person (Oxley et al., 2018; Sarcey et al., 2017), were unneutered (Patronek et al., 2013; Shuler et al., 2008), and lived exclusively outdoors (Gershman et al., 1994). Although wide variation was observed between breeds, German Shepherds were the most commonly reported breed (Oxley et al., 2018; Sarcey et al., 2017).

With the results from the third section of the questionnaire we confirmed our hypothesis. While previous studies have described bites during direct interaction as the most common (Gautret et al., 2013; Oxley et al., 2018; Sarcey et al., 2017), in our study, only half of the reported bites occurred during voluntary interaction with the dog. The other half of bites was reported in situations without prior interaction with the dog, namely during fast movements around the dog, while getting into close proximity to the dog and during incidents described as without a reason. These incidents occurred in public spaces, mainly in the street or on the road and involved purebred dogs with history of aggression. Our findings suggest a more complex contextual aspect of dog bites and indicate that knowledge of bites without prior interaction is equally important, if not more important, as they are more difficult to prevent.

In further examining the role of humans on dogs' aggression, the second study assessed psychosocial factors, namely dog and owner personality traits and owner attachment styles. Previously, personality traits related to dog aggression have only been assessed using owner-reported questionnaire data. In dog studies, lower sociability has been associated with child-directed and stranger-directed aggression (Kaneko et al., 2013), and higher fearfulness with fear-directed and dog-directed aggression (Haverbeke et al., 2009; Arata et al., 2014). In human studies, owners with lower agreeableness, emotional stability, extraversion and conscientiousness have been associated with dogs aggressive towards owners (Dodman et al 2018). Attachment styles, namely insecure attachment styles, have not been studied in relation to dog aggression, but previous studies revealed that they play a role in the occurrence of behaviour problems in dogs (Konok et al., 2015) and in the formation of behavioural strategies in threatening situations (Rehn et al., 2017). Based on existing research we predicted that the above mentioned traits are associated with dog aggression.

Data collection using owner-reported questionnaires has a limitation of owner bias and their possibly limited knowledge of dog behaviour (Wiener and Haskell, 2016). To be more objective, psychosocial factors were assessed in our study using a combination of questionnaires and behavioural test. Data on the history of dog aggression were collected using parts of the Canine Behavioral Assessment and a Research Questionnaire (C-BARQ) related to owner-directed, stranger-directed, dog-directed aggression and chasing (Hsu and Serpell, 2003). Dogs' personality traits, defined as playfulness, curiosity, chase-proneness, sociability, aggressiveness and shyness/boldness, were assigned to each dog using a behavioural test called the Dog Mentality Assessment (DMA) (Svartberg and Forkman, 2002). The test consisted of nine subtests performed outside in a specially set up testing area. The owner was present during the test. In the first subtest, a stranger made the first contact with the dog, and in the second, he she played with the dog. In the third subtest, the dog's response to a moving object was observed. In the fourth, the passive state of the dog and the owner was observed. In the fifth subtest, the dogs' response to the unusual behaviour of a stranger was observed, and in the sixth, to the sudden appearance of a puppet. In the seventh subtest, the dogs' response to the sudden sound of metal was observed, and in the eighth to the slow approach of two people covered with a sheet. In the last subtest, the stranger played with the dog again. Behaviour during the test was videotaped and analysed using a predefined ethogram. Owner personality traits, defined as extraversion, agreeableness, conscientiousness, neuroticism and openness, were assessed with an abbreviated version of the Big Five Inventory Questionnaire (BFI-10) (Rammstedt and John, 2007). Attachment styles, namely pet-related anxiety and avoidance, were assessed using the Experiences and Close Relationship-Revised Questionnaire - ECR-R (Beck and Madresh, 2008).

The results on the dog personality showed sociability is the only trait associated with aggression, which partially confirms our hypothesis. It semms that highly sociable dogs have better social control and are more comfortable in situations that can increase stress levels and potentially trigger aggression (Yang et al., 2017). Also, in terms of owner personality, only owners with higher scores for neuroticism were associated with dogs aggressive towards strangers and other dogs, partially confirming our hypothesis. Neurotic owners appear to have a certain behaviours and physiological traits that influence their dog's behaviour. For example, they may exhibit unpredictable styles of caretaking, potentially decreasing social control of their dogs, which can lead to increased stress levels (Finka et al., 2019). In addition, neurotic owners themselves have higher stress and cortisol levels (Schöberl et al., 2012). They also seem to choose dog breeds they classify as more aggressive (Egan and MacKenzie, 2012).

Regarding attachment styles, both anxious and avoidant attachment styles have been associated with aggression. Anxious attachment style is manifested as clinginess, control, closeness and support seeking (Shaver and Mikulincer, 2002), whereas avoidant attachment style as distancing from the others, insufficient intimate contact, affection and availability (Hazan and Shaver, 1987). Owners with lower scores for anxious attachment were associated with dogs that had high scores for stranger-directed aggression. This result is in contrast to reports on mother-infant attachment (Amani, 2016) and it appears that owners' behaviour related to anxious attachment do not influence their dog aggressive behaviour. In contrast, owners with higher scores on avoidant attachment were associated with dogs that had higher scores on owner-directed aggression. In this case, behaviours related to avoidant attachment, appear to play a role in the dog's aggression. It seems that dogs of dogs of owners with avoidant style of attachment perceive the lack of a secure base (Finka et al.,

2019) stressful, especially in aversive situations (Rehn et al., 2017), possibly leading to more frequent display of aggression. Overall, we were the first to confirm the association between owners' anxious and avoidant attachment styles and dog aggression.

Another novel observation regarding aggression was made in our third study. For the first time, the association between various aspects of inhibitory control and dog aggression was examined. Inhibitory control is a part of executive control, a higher-order cognitive process, involved in self-regulation of actions and emotions (Séguin and Zelazo, 2005). It can be defined as the ability to block the execution of an immediate response in favour of a delayed but more rewarding behaviour (Bray et al. 2014) and is not a unitary mechanism, but a collection of separate cognitive processes (Beran, 2015; Brucks et al., 2017). Commonly described are self-control, cognitive inhibition and motor inhibition (Brucks et al., 2017; Brucks et al., 2019). Self-control can be defined as the ability to control impulse responses (Beran, 2015) and is usually assessed with an exchange paradigm, when an individual must resist immediate reward, in favour of a better, but delayed reward (Mischel et al., 1989). Cognitive inhibition is described as the ability to regulate the contents of the working memory, by removing information that is irrelevant in a given situation (Hasher et al., 1999). It is usually assessed using an object discrimination paradigm in which two stimuli change their reward contingencies, after an initial discrimination (Milgram et al., 1994). Both, impairments in self-control and cognitive inhibition, have previously been associated with aggression in humans (Mitchell et al., 2006; Herndon et al., 2015), but there has been no research on the association with dog aggression. We predicted that aggressive dogs will exhibit poor performance in both paradigms.

To assess aggression in a controlled environment, a standardized behavioural test called Socially Acceptable Behavior (SAB) (Planta and De Meester, 2007) was used. The test was performed outside in a specially set up testing area and consisted of 16 subtests, known to elicit dog aggression. The owner or handler was present only for the first eight and for the last subtest. In the first subtest, a person approached the dog and tried to pet it with an artificial plastic hand and in the second, the dog was led past a moving sheet. In the third subtest, the silhouette of a big black cat suddenly appeared in front of the dog, in the fourth, the dog was led past a suddenly activated horn, and in the fifth, past a sudden sound of metal (rattling cans). In sixth and seventh subtests, three people approached the dog, first in slow and then in fast walking. In the eighth subtest, a toy dog of similar in size was placed in front of the dog and in the ninth, a person approached the dog and tried to pet it with an artificial hand. In the tenth subtest, a bell rang in front of the dog, and on the eleventh, an umbrella was opened and closed. In the twelfth subtest, a sled with a doll on it was pulled past the dog and in the thirteenth, a person approached the dog and tried to pet it with a doll. In fourteenth tasks, a person approached the dog in a threatening manner and stared at it, and in the fifteenth, the same person tried to touch the dog with an artificial hand. In the sixteenth subtest, the owner or handler approached the dog and tried to pet it with a doll. Behaviour during the test was video recorded and it was observed whether the dog showed no aggression, only threatening behaviour or aggressive biting behaviour.

Self-control was measured using the delay of gratification test, modified after Brucks et al. (2017). In this test the dog had to resist eating an accessible but low-quality reward (LQR) and wait for delayed but high-quality reward (HQR). The test was conducted indoors using a wooden enclosure and consisted of three parts: food preference test (to determine LQR and HQR for each dog), training trails (to familiarize the dogs with the procedure), and test sessions. Rewards were presented on top of two plastic bowls that were simultaneously pushed towards the dog. The LQR bowl entered the enclosure first, and if the dog did not eat the reward, it was replaced by the HQR bow, after a 2-second delay. As the test progressed, the delay time was increased. The measures of inhibition were the number of successful trails and the maximum delay time achieved.

Cognitive inhibition was measured using the reversal learning test, modified after Brucks et al. (2017). The test required the dog to inhibit a learned response and shift the behaviour to a new object-reward contingency. The test was conducted indoors in front of a wooden enclosure and consisted of two phases: the acquisition phase and the reversal phase. In the acquisition phase, the dog learned that one of the two presented differently shaped bowls always contained a reward. After the dog correctly identified the bowl containing the reward enough times and reached a learning criterion, the reversal phase followed. In this phase, the position of the reward was change, and the other bowl now contained the reward. At this point, the dog had to correctly identify the bowl containing the reward. The measures of inhibition were the number of correct choices during the last acquisition (last session during acquisition phase when the dog reached the criterion) and the reversal phase.

The results confirmed our hypothesis for self-control but not for cognitive inhibition. Dogs that performed poorly on the delay of gratification test were those that showed severe signs of aggression during SAB. This result was observed for the first time in dogs and is consistent with research findings in humans (Herndon et al., 2015) and rats (Van den Bergh et al., 2006). Interestingly, the performance in the delay of gratification is also an indicator of impulsivity, and a lack of self-control can also be labelled as impulsivity (Wright et al. 2011). It could be that dogs with poor performance on the delay of gratification test in our study were impulsive, since it was suggested that impulsive dogs show fewer or no warning signs before acting aggressively (Fatjó et al., 2005). The found link between impulsivity and dog aggression is in line with reports in humans (Blair, 2016), non-human primates (Ferrari et al., 2005) and rats (Ferrari et al., 2005) and appears to be consistent across many mammalian species.

No association was found between cognitive inhibition and aggression. We believe that reason for this lies in the population included in the human studies. Reversal learning in relation to aggression has been studied mainly among patients with psychiatric disorders (Turgay, 2004), which makes a comparison with dogs very difficult. It could also be because frustration is the main factor that contributes to aggression in humans with psychiatric disorders (Blair, 2010). Frustration in dogs has only been studied in the context of food (Jakovcevic et al., 2013; Bremhorst et al., 2019; Dzik et al., 2019), making the aforementioned studies difficult to compare. Furthermore, because performance in one paradigm and not both was associated with aggression, this further supports the context specificity of inhibitory control measures suggested previously (Bray et al., 2014; Brucks et al., 2017; Vernouillet et al., 2018) and implies that not all aspects of inhibitory control are associated with a particular behaviour, such as aggression.

The final study addressed physiological activation during aggression, by simultaneously recording behaviour, cardiovascular and neuroendocrine parameters. Previous studies revealed several physiological parameters known to play a role in aggression. Two important neuroendocrine changes were proposed to be the increase in cortisol (Rosado et al., 2010) and the decrease in serotonin concentrations (Çakiroğlu et al., 2007; Rosado et al., 2010; León et al., 2012). However, these studies had major shortcomings as they focused only on observing neuroendocrine changes between groups of dogs with or without a history of aggression, and not on observing changes during aggression in real-time. The most common cardiovascular parameter studied in the context of aggression is heart rate (Craig et al., 2017), but due to movement during aggression, and greater possibility of moving artefacts (Essner et al., 2015), non-contact observation of surface temperature has been suggested as a better alternative (Travain et al., 2015). The majority of studies assessing surface temperature in dogs and other animals, reported on decreased temperature during aversive situations (Ludwig et al., 2007; Kuraoka and Nakamura, 2011; Part et al., 2014; Travain et al., 2015; Boileau et al., 2019). In addition, it has been previously argued that it is important to measure multiple physiological parameters simultaneously while observing behaviour in real-time (Reefmann et al., 2009). Taking into account all the limitations of previous studies, the aim of our study was to assess cardiovascular and neuroendocrine changes during aggression in real-time, simultaneously and non-invasively. We predicted increased salivary cortisol concentration, decreased salivary serotonin concentration and decreased body and facial surface temperature during aggression.

In this study, SAB test (Planta and De Meester, 2007) was also used. Behaviour during the test was videotaped and analysed using predefined ethogram. Dogs exhibiting or not exhibiting biting behaviour during the test were categorized as aggressive or non-aggressive, respectively. Cortisol and serotonin samples were obtained from dogs' saliva by the owners or handlers, using commercially available cotton swabs. Saliva samples were collected three times, immediately before the participation in the SAB test (pre-test samples), immediately after for serotonin and 20 min after for cortisol samples (post-test samples) and in the home environment, when the dog was resting at home (home samples). Surface temperature, using infrared thermography was also measured at three occasions. Thermographic infrared images of the dogs' face area (frontally) and body side (laterally) were taken immediately before the participation in the SAB test (pre-test images) and immediately after (post-test images). 16 images of the face area were also taken during SAB test, at the completion of each subtest (during the test images).

The results only partially confirmed our hypotheses. As expected, we found association between dogs' aggression in real time and lower salivary serotonin concentration. Our observations are consistent with the serotonin deficiency hypothesis, previously observed in humans (Duke et al., 2013) and non-human animals (Ferrari et al., 2005). Lower serotonin has also been associated with impaired impulse control (Reisner et al., 1996) and is known to be a neural regulator and inhibitor of aggressive reactivity (Summers and Winberg, 2004). Such association was not found between aggression and cortisol concentration (CORT), but we observed higher pre-test CORT compared to CORT in the home environment, indicating CORT may indicate emotional arousal, and not necessarily emotional valence (Lewandowski et al., 2014) due to arrival in a new environment, meeting of strangers (Ng et al., 2014) or anticipation of an activity (Horváth et al., 2008).

The results regarding surface temperature also did not match our predictions. While we did not observe any changes in post-test values compared to pre-test values, we did observed increase in facial temperature in the aggressive dogs during the test. A similar increase in surface temperature during dog aggression was reported by Rigterink et al. (2018). However, in their study, only 27% of the dogs in the aggressive group actually displayed stranger-directed aggression, and the temperature increase was observed in both the aggressive and non-aggressive group. It appears that surface temperature also reflects emotional arousal and not necessary emotional valence, as its increase has previously been observed in dogs during positive situations (Travain et al., 2016) and negative situations (Travain et al., 2015). Although our initial hypotheses are not fully confirmed both the cardiovascular and neuroendocrine systems appear to be active during aggression in real-time.

In this study, a novel aggression-related behaviour was observed in addition to standard aggression-related behaviours (e.g., biting, snapping) (Netto and Planta, 1997; Haverbeke et al., 2009). Dogs exhibiting aggression showed increased frequency of tail wagging and left tail wagging bias. Not related to aggression, Quaranta et al. (2007) observed asymmetrical tail wagging during stimuli with different emotional valence, with right tail wagging bias during positive stimuli, and left tail wagging bias during negative stimuli. Since left tail wagging is under the influence of the right brain hemisphere (Buxton and Goodman, 1967), our result further confirms the specialization of right brain hemisphere for expression of intense emotions in dogs and other animals (Rogers, 2010; Siniscalchi et al., 2019).

4.2 POVZETEK

Agresivnost je del normalnega obnašanja psov in jo lahko kategoriziramo kot agresivno grožnjo (npr. renčanje, kazanje zob) ali agresivno grizenje (npr. šavsanje, napadanje) (Netto in Planta, 1997). Kadar je agresivnost usmerjena proti lastniku ali drugim ljudem, velja za eno izmed najbolj nezaželenih in nevarnih obnašanj pri psih. Kljub temu, da precejšnje število ljudi, zlasti otrok (Súilleabháin, 2015), ugrizne pes in da je agresivnost pogost razlog, da lastniki psa zapustijo, evtanazirajo ali odpeljejo v zavetišče (Salman in sod., 2000; Diesel in sod., 2008), še vedno obstajajo velike vrzeli v znanju o agresiji psov. Cilj te disertacije je bil zapolniti te vrzeli s pomočjo štirih ločenih študij, od katerih je vsaka raziskovala posamezen vidik tega obnašanja. Raziskovanje agresije iz različnih zornih kotov smo začeli z zunanjimi dejavniki, in sicer z raziskovanjem okolja in interakcije z ljudmi. Nato smo prešli na psihosocialne in kognitivne dejavnike ter zaključili s fiziološkimi dejavniki.

V svoji prvi študiji o kontekstih in interakciji z ljudmi smo se osredotočili izključno na agresivno grizenje. Prejšnje raziskave v zvezi z ugrizi psov so večinoma poročale o značilnostih vpletenih psov, kot so pasma, starost in spol, ter o posledicah po ugrizu za psa (Salman in sod., 2000; Diesel in sod., 2008; Oxley in sod., 2018). Pogosto so tudi opisovali posledice in značilnosti žrtev, na primer njihovo starost in spol, lokacijo in resnost ugriza (Rosado in sod., 2009; Horisberger in sod., 2004; Oxley in sod., 2018). Avtorji so poročali, da se večina ugrizov zgodi med neposredno interakcijo človeka in psa, na primer med božanjem ali igranjem (Rosado in sod., 2009; Horisberger in sod., 2004; Oxley in sod., 2018) in na zasebni posesti (Oxley in sod., 2018). V večini študij primanjkuje natančnejši opis ugrizov psov, zlasti podrobnejši pregled okoliščin, v katerih je do ugriza prišlo. V študiji smo domnevali, da bo poglobljeno raziskovanje ugrizov psov, ki ni omejeno le na ugrize med neposredno interakcijo s psom, vodilo do večjega števila kontekstov ugrizov, kot so poročali v preteklost (Oxley in sod., 2018).

Za pridobitev teh informacij smo uporabili spletni vprašalnik, ki je vseboval 29 vprašanj. Šest odprtih in 23 zaprtih vprašanj smo razdelili v štiri sklope. Prvi in drugi sklop sta se dotaknila demografije žrtev in udeleženih psov. Tretji se je osredotočil na natančen opis incidenta ugriza, obnašanje psa in žrtve in lokacijo ter zadnji na posledice za psa po ugrizu. Rezultati prvih dveh sklopov so bili v skladu s prejšnjimi raziskavami. Večino ljudi je pes ugriznil, ko so bili otroci ali najstniki (Bregman in Slavinski, 2012; Touré in sod., 2015). Psi so bili v glavnem veliki, žrtvi poznani odrasli samci. Prišli so od vzreditelja ali poznane osebe (Oxley in sod., 2018; Sarcey in sod., 2017), niso bili kastrirani ali sterilizirani

(Patronek in sod., 2013; Shuler in sod., 2008) in živeli so izključno na prostem (Gershman in sod, 1994). Kljub veliki raznolikosti med pasmami so najpogosteje poročali o nemških ovčarjih (Oxley in sod., 2018; Sarcey et al., 2017).

Z rezultati tretjega sklopa vprašalnika smo potrdili zastavljeno hipotezo. Medtem ko so prejšnje raziskave ugrize med neposredno interakcijo označile kot najpogostejše (Gautret in sod., 2013; Oxley in sod., 2018; Sarcey in sod., 2017), je v naši študiji prišlo le pri polovici opisanih ugrizov med prostovoljno interakcijo s psom. Za drugo polovico ugrizov so poročali, da so se zgodili v situacijah brez predhodne interakcije s psom, in sicer med hitrimi gibi okoli psa, medtem ko so se posredno približali psu in v primerih, opisanih kot brez razloga. Ti incidenti so se zgodili na javnem kraju, predvsem na ulici ali na cesti in so vključevali čistokrvne pse z zgodovino agresije. Naše ugotovitve nakazujejo na bolj zapleten kontekstualni vidik ugriza psov in da je znanje o ugrizih brez predhodne interakcije prav tako pomembno, če ne celo pomembnejše, saj jih je težje preprečiti.

Za nadaljnje raziskovanje vplivov človeka na agresijo psa je bila v drugi študiji raziskana povezanost psihosocialnih dejavnikov, in sicer lastnosti osebnosti psov in lastnikov ter stilov navezanosti lastnikov. Doslej so bile v kontekstu agresije psov lastnosti osebnosti ocenjene le z uporabo vprašalnikov, ki so jih izpolnili lastniki. V raziskavah na psih je bila nižja stopnja družabnosti povezana z agresijo, usmerjeno proti otrokom in tujcem (Kaneko in sod., 2013), medtem ko je bila večja plašnost povezana z agresijo, usmerjeno proti psom in agresijo, povezano s strahom (Haverbeke in sod., 2009; Arata in sod., 2014). V študijah na ljudeh so bili lastniki z nižjo sprejemljivostjo, čustveno stabilnostjo, ekstravertiranostjo in vestnostjo povezani s psi, agresivnimi do lastnikov (Dodman in sod., 2018). Stili navezanosti, in sicer negotovi stili navezanosti, še niso bili raziskani v povezavi z agresijo psov, vendar so prejšnje študije pokazale, da igrajo vlogo pri pojavu nezaželenega obnašanja pri psih (Konok in sod., 2015) in oblikovanju strategij obnašanja v ogrožajočih situacijah (Rehn in sod., 2017). Na temelju obstoječih raziskav smo predvideli, da bodo vse zgoraj omenjene lastnosti povezane z agresijo psov.

Zbiranje podatkov na podlagi poročanja lastnikov omejujeta lastnikova pristranskost in potencialno omejeno znanje o obnašanju psov (Wiener in Haskell, 2016), zato smo za večjo objektivnost psihosocialne dejavnike v svoji študiji ocenili s kombinacijo vprašalnikov in testiranja obnašanja. Podatki o zgodovini agresije psov so bili pridobljeni z uporabo delov vprašalnika C-BARQ, povezanih z agresijo do lastnikov, tujcev, psov in z lovljenjem (Hsu in Serpell, 2003). Lastnosti osebnosti psov, opredeljene kot igrivost, radovednost, nagnjenost k lovljenju, družabnost, agresivnost in plašnost/neustrašnost, so bile vsakemu psu dodeljene s testom obnašanja DMA (Svartberg in Forkman, 2002). Test je obsegal devet nalog, izvedenih zunaj na posebej pripravljanjem testnem polju. Lastnik je bil prisoten pri vseh nalogah. Pri prvi nalogi je neznana oseba vzpostavila prvi stik s psom, pri drugi pa se s psom igrala. Pri tretji nalogi se je opazoval odziv psa na premikajoči se predmet. Pri četrti nalogi se je opazovalo pasivno stanje psa in lastnika. Pri peti nalogi se je opazoval odziv psa na nenavadno obnašanje neznane osebe, pri šesti pa na nenaden pojav lutke. Pri sedmi nalogi se je opazoval odziv psa na nenaden zvok kovine, pri osmi pa na počasno približevanje dveh oseb, ki sta prekriti z rjuho. Pri zadnji nalogi se je neznanec ponovno igral s psom. Obnašanje med testom je bilo posneto in analizirano s pomočjo vnaprej pripravljenega etograma. Lastnosti osebnosti lastnikov, opredeljene kot ekstravertnost, sprejemljivost, vestnost, nevroticizem in odprtost, so bile ocenjene s skrajšano različico vprašalnika BFI-10 (Rammstedt in John, 2007). Stila navezanosti, in sicer anksiozna in izogibajoča navezanost do hišnih ljubljenčkov, sta bili določena z vprašalnikom ECR-R (Beck in Madresh, 2008).

Rezultati osebnosti psov so pokazali, da je družabnost edina lastnost, povezana z agresijo, kar delno potrjuje našo hipotezo. Zdi se, da imajo zelo družabni psi boljši družbeni nadzor in so bolj sproščeni v situacijah, ki lahko povišajo raven stresa in potencialno povzročijo agresijo (Yang in sod., 2017). Pri proučevanju lastnosti osebnosti lastnikov so bili le lastniki z višjimi ocenami nevroticizma povezani s psi, agresivnimi do tujcev in drugih psov, kar je delno potrdilo našo hipotezo. Zdi se, da imajo nevrotični lastniki posebne vedenjske in fiziološke lastnosti, ki vplivajo na obnašanje njihovega psa. Na primer, kažejo lahko nepredvidljive sloge oskrbe, kar lahko zmanjša družbeni nadzor njihovih psov in potencialno povzroči višjo raven stresa (Finka in sod., 2019). Poleg tega imajo nevrotični lastniki psov tudi sami višjo raven stresa in kortizola (Schöberl in sod., 2012). Prav tako se zdi, da takšni lastniki izbirajo pasme psov, za katere menijo, da so agresivnejše (Egan in MacKenzie, 2012).

Kar zadeva stila navezanosti lastnika na psa, sta bili tako anksiozna kakor tudi izogibajoča navezanost povezani z agresijo. Anksiozna navezanost se izraža kot oklepajoče obnašanje, iskanje nadzora, bližine in podpore (Shaver in Mikulincer, 2002), medtem ko se izogibajoča navezanost izraža kot distanciranje od drugih, pomanjkanje intimnih stikov, naklonjenosti in razpoložljivosti (Hazan in Shaver, 1987). Lastniki z nižjimi ocenami anksiozne navezanosti so bili povezani s psi, ki so dosegli visoko oceno za agresijo, usmerjeno proti tujcem. Ta ugotovitev je v nasprotju z raziskavami o navezanosti matere na dojenčka (Amani, 2016) in zdi se, da obnašanje lastnikov, povezano z anksiozno navezanostjo, ne vpliva na agresivno obnašanje njihovega psa. Nasprotno so bili lastniki z višjimi ocenami izogibajoče navezanosti povezani s psi z višjimi ocenami agresije, usmerjene proti lastnikom. V tem primeru se zdi, da obnašanje, povezano z izogibajočo navezanostjo, igra vlogo pri pojavnosti agresije psov. Zdi se, da psom lastnikov z izogibajočim stilom navezanosti primanjkuje varna baza (Finka in sod., 2019) in to dojemajo kot stresno, zlasti v negativnih situacijah (Rehn in sod., 2017), kar lahko povzroči pogostejše izkazovanje agresije. Na splošno smo bili prvi, ki smo potrdili odnos med anksiozno in izogibajočo navezanostjo lastnikov in njihovih psov ter agresijo psov.

Do novega odkritja v povezavi z agresijo je prišlo tudi v tretji študiji. Prvič je bila raziskana povezava med različnimi vidiki inhibicijske kontrole in agresijo psov. Inhibicijska kontrola je del izvršnega nadzora, kognitivnega procesa visokega reda, vključenega v samouravnavanje obnašanja in čustev (Séguin in Zelazo, 2005). Opredelimo jo lahko kot sposobnost zaustavitve takojšnjega odziva v korist zakasnjenega, a koristnejšega obnašanja (Bray in sod. 2014). Ne gre za enoten mehanizem, ampak za zbirko ločenih kognitivnih procesov (Beran, 2015; Brucks in sod., 2017). Pogosto opisani procesi so samonadzor, kognitivna in motorična inhibicija (Brucks in sod., 2017; Brucks in sod., 2019). Samonadzor lahko opišemo kot sposobnost nadzora impulzivnih odzivov (Beran, 2015) in se običajno ocenjuje s paradigmo izmenjavanja, med katero se mora posameznik upreti takojšnji nagradi v korist boljše, vendar zakasnjene nagrade (Mischel in sod., 1989). Kognitivno inhibicijo lahko opredelimo kot regulativno sposobnost v delovnem spominu, ki odstranjuje v dani situaciji nepomembne informacije (Hasher in sod., 1999). Običajno jo ocenjujemo s paradigmo razločevanja predmetov, med katero dva dražljaja po začetni razločitvi spremenita položaj nagrade (Milgram in sod., 1994). Obe, okvara samonadzora in kognitivna inhibicija, sta bili povezani z agresijo pri ljudeh (Mitchell in sod., 2006; Herndon in sod., 2015), vendar raziskav o povezanosti z agresijo psov še ni bilo. Mi smo predvidevali, da bodo agresivni psi v obeh paradigmah pokazali slabe rezultate.

Za oceno agresivnosti v nadzorovanem okolju je bil uporabljen standardiziran test obnašanja SAB (Planta in De Meester, 2007). Test je bil izveden zunaj na posebej pripravljenem testnem polju in je obsegal 16 nalog, za katere je znano, pri psih izzovejo agresivne odzive. Lastnik ali vodnik je bil prisoten le pri prvih osmih nalogah in pri zadnji nalogi. Pri prvi nalogi se je oseba približala psu in ga poskušala pobožati s plastično umetno roko. Pri drugi nalogi se je psa peljalo mimo premikajoče se rjuhe. Pri tretji nalogi se je pred psom nenadoma prikazala silhueta velike črne mačke. Pri četrti nalogi se je psa peljalo mimo nenadoma aktivirane troblje, pri peti pa mimo nenadoma povzročenega zvoka kovine. Pri šesti in sedmi nalogi so se tri osebe približale privezanemu psu, najprej v počasni, nato pa v hitri hoji. Pri osmi nalogi se je pred psa postavilo lutko njemu podobno velikega psa. Pri deveti nalogi se je oseba približala psu in ga poskušala pobožati z umetno roko. Pri deseti nalogi se je pred psom zvonilo z zvončkom, pri enajsti pa odpiralo in zapiralo dežnik. Pri dvanajsti nalogi so bile mimo psa povlečene sani, na katerih je bila lutka. Pri trinajsti nalogi se je oseba približala psu in poskušala pobožati z lutko. Pri štirinajsti nalogi se je oseba grozeče približala psu in vanj strmela, pri petnajsti pa ga ta ista oseba poskušala pobožati z umetno roko. Pri šestnajsti nalogi se je lastnik ali vodnik prijazno približal psu in ga poskušal pobožati z lutko. Obnašanje med testom je bilo posneto in opazovano je bilo, ali pes ne kaže agresije, kaže samo grožnjo ali agresivno grizenje.

Samonadzor smo merili s testom zapoznelega nagrajevanja, modificiranega po Brucks in sod. (2017). Med testom se je pes moral upreti vzgibu, da bi pojedel dostopno, a manj kakovostno nagrado (NKN) in počakal na zapoznelo, a bolj kakovostno nagrado (VKN). Test je bil izveden v lesenem ohišju in je bil sestavljen iz treh delov: testa izbire hrane (za določitev VKN in NKN za vsakega psa), treninga (za seznanitev psov s postopkom) in testnega dela. Nagrade so bile ponujene na dveh plastičnih posodah, ki sta bili hkrati potisnjeni proti psu. NKN-posoda je prva vstopila v ohišje in če pes ni pojedel nagrade, je bila po 2 sekundah zakasnitve zamenjana za VKN-posodo. Med testom se je čas zakasnitve povečeval. Merili inhibicije sta bili število uspešnih poskusov in najvišji doseženi čas zakasnitve.

Kognitivna inhibicija je bila izmerjena s testom obratnega učenja, modificiranim po Brucks in sod. (2017), med katerim se je moral pes upreti naučenemu odziv in preusmeriti obnašanje v korist nove pozicije nagrade. Test je bil izveden v notranjih prostorih in je bil sestavljen iz dveh faz: faze usvojitve in faze obratnega učenja. V fazi usvojitve je bilo psu prikazano, da ena od dveh predstavljenih posod, različnih oblik in velikosti, vedno vsebuje nagrado. Po tem, ko je pes dovoljkrat pravilno identificiral posodo, ki vsebuje nagrado in dosegel merilo, je sledila faza obratnega učenja. V tej fazi se je položaj nagrade spremenil, saj je bil prestavljen pod drugo posodo. Na tej točki je moral pes znova pravilno prepoznati posodo z nagrado. Merilo inhibicijske kontrole je bilo število uspešnih izbir med zadnjo fazo usvojitve (ko je pes dosegel merilo) in fazo obratnega učenja.

Rezultati so potrdili našo hipotezo o samonadzoru, vendar ne tudi o kognitivni inhibiciji. Psi, ki so se med testom zapoznelega nagrajevanja slabo odrezali, so bili tisti, ki so med SAB pokazali hude znake agresije. Ta ugotovitev je bila prvič opažena pri psih in je v skladu z raziskavami pri ljudeh (Herndon in sod., 2015) in podganah (Van den Bergh in sod., 2006). Zanimivo je, da je neuspešnost pri nalogi zapoznelega nagrajevanja tudi kazalnik impulzivnosti, medtem ko se pomanjkanje samonadzora lahko imenuje tudi impulzivnost (Wright in sod., 2011). Zdi se, da so bili psi, ki so bili v naši študiji slabi pri testu zapoznelega nagrajevanja, impulzivni, saj je glede na Fatjó in sod. (2005) za impulzivne pse značilno, da imajo pred agresijo odsotno ali zmanjšano kazanje opozorilnih znakov. Ugotovljena povezava med impulzivnostjo in agresijo pri psih je v skladu z raziskavami pri ljudeh (Blair, 2016), primatih (Ferrari in sod., 2005) in podganah (Ferrari in sod., 2005) in se zdi konsistentna pri več vrstah sesalcev.

Med kognitivno inhibicijo in agresijo povezave nismo odkrili. Menimo, da je razlog za to populacija, vključena v študije na ljudeh. Obratno učenje v povezavi z agresijo so preučevali predvsem pri bolnikih s psihiatričnimi patologijami (Turgay, 2004), zaradi česar je primerjanje s psi zelo težko. Drugi razlog lahko prestavlja frustracija, ki velja za glavni dejavnik, ki prispeva k agresivnosti pri ljudeh s psihiatričnimi patologijami (Blair, 2010). Frustracija pri psih je bila raziskana le v kontekstu hrane (Jakovcevic in sod., 2013; Bremhorst in sod., 2019; Dzik in sod., 2019), zaradi česar je omenjene študije težko primerjati s študijami o agresiji. Ker smo odkrili povezanost med agresijo in samo eno od dveh kognitivnih paradigem, to dodatno podpira predlagano individualnost kontekstov pri merjenju inhibicijskega nadzora pri psih (Bray in sod., 2014; Brucks in sod., 2017; Vernouillet in sod., 2018) in nakazuje, da niso vsi vidiki inhibicijske kontrole povezani s posameznim obnašanjem, kot je na primer agresija.

Četrta študija se je dotaknila fiziološke aktivacije med agresijo psov s hkratnim spremljanjem obnašanja, kardiovaskularnih in nevroendokrinih parametrov. Prejšnje raziskave so pokazale več fizioloških parametrov, za katere je znano, da igrajo vlogo pri agresiji. Dva glavna predlagana nevroendokrina parametra sta povišan kortizol (Rosado in sod., 2010) in znižan serotonin (Çakiroğlu in sod., 2007; Rosado in sod., 2010; León in sod., 2012). Vendar so imele te študije veliko pomanjkljivost, saj so se osredotočile le na opazovanje nevroendokrinih sprememb med skupino psov z ali brez zgodovine agresije in ne na opazovanje sprememb med agresijo v realnem času. Najpogostejši kardiovaskularni parameter, raziskan v zvezi z agresijo, je srčni utrip (Craig in sod., 2017), vendar je zaradi gibanja med agresijo in večje možnosti merilnih napak ob premikanju (Essner in sod., 2015) brezstično merjenje temperature površine telesa boljša alternativa (Travain in sod., 2015). Večina študij, ki so raziskovale površinsko temperaturo pri psih in drugih živalih, je poročala o znižani temperaturi v negativnih situacijah (Ludwig in sod., 2007; Kuraoka in Nakamura, 2011; Part in sod., 2014; Travain in sod., 2015; Boileau in sod., 2019). Pred tem je bilo tudi predlagano, da je pomembno hkrati meriti več fizioloških parametrov ob opazovanju obnašanja v realnem času (Reefmann in sod., 2009). Glede na vse omejitve prejšnjih raziskav je bil cilj naše študije oceniti hkratne kardiovaskularne in nevroendokrine spremembe med agresijo v realnem času in neinvazivno. Predvideli smo povišano koncentracijo kortizola v slini, znižano koncentracijo serotonina v slini ter znižano površinsko telesno in obrazno temperaturo med agresijo.

Med to študijo je bil uporabljen tudi standardiziran test obnašanja SAB (Planta in De Meester, 2007). Obnašanje med testom je bilo posneto in analizirano z uporabo vnaprej določenega etograma. Psi, ki so med preskusom prikazali ali niso prikazali agresivnega grizenja, so bili kategorizirani kot agresivni oziroma neagresivni. Lastniki ali vodniki so vzorce kortizola in serotonina s komercialno dostopnimi bombažnimi tamponi pridobili iz sline psov. Vzorci sline so bili odvzeti trikrat, tik pred udeležbo na testu SAB (vzorci pred testom), takoj po izvedbi testa za vzorce serotonina in 20 minut kasneje za vzorce kortizola (vzorci po testu) ter v domačem okolju, ko je pes počival doma (domači vzorci). Trikrat je bila z infrardečo termografijo merjena tudi površinska temperatura. Termografske infrardeče slike področja obraza psov (od spredaj) in strani telesa (bočno) so bile posnete tik pred udeležbo na testu SAB (slike pred testom) in takoj po tem (slike po testu). Med testom SAB je bilo ob zaključku vsake od šestnajstih naloge posneta tudi slika obraza (slike med testom).

Rezultati so le delno potrdili naše hipoteze. Kot pričakovano smo ugotovili povezavo med psi, agresivnimi v realnem času, in nižjo koncentracijo serotonina v slini. To, kar smo opazili, se imenuje hipoteza o pomanjkanju serotonina, ki jo lahko opazimo pri ljudeh (Duke in sod., 2013) in drugih živalih (Ferrari in sod., 2005). Znižan serotonin je povezan tudi s slabim nadzorom impulzivnosti (Reisner et al., 1996) in velja za regulator v možganih ter inhibitor agresivne reaktivnosti (Summers in Winberg, 2004). Takšne povezave med agresijo in koncentracijo kortizola (CORT) nismo ugotovili, vendar smo opazili višji domači CORT, v primerjavi s CORT pred testom, kar kaže, da lahko spremembe v CORT prikazujejo čustveno vzburjenje zaradi prihoda v novo okolje, srečanja tujcev (Ng in sod., 2014) ali pričakovanja dejavnosti (Horváth in sod., 2008) in ne nujno čustveno valenco (Lewandowski in sod., 2014),

Tudi rezultati glede površinske temperature niso bili v skladu z našimi napovedmi. Čeprav nismo ugotovili nobenih sprememb ob primerjanju vrednosti pred in po testu, smo pri slikah, pridobljenih med testom, zabeležili zvišanje temperature obraza pri agresivnih psih. O podobnem zvišanju površinske temperature med agresijo pri psih so poročali Rigterink in sod. (2018), vendar je v njihovi študiji le 27 % psov v agresivni skupini dejansko pokazalo agresijo, usmerjeno proti tujcem, medtem ko so zvišanje temperature opazili tako v agresivni kot tudi v neagresivni skupini. Zdi se, da lahko tudi površinska temperatura odraža čustveno vzburjenje in ne nujno čustveno valenco, saj so o njenem zvišanju že poročali pri psih, tako v pozitivnih (Travain in sod., 2016) kot tudi v negativnih situacijah (Travain in sod., 2015). Čeprav naše začetne hipoteze niso bile v celoti potrjene, se zdi, da se med agresivnostjo pri psih aktivirata tako kardiovaskularni kakor tudi nevroendokrini sistem.

Med to študijo smo poleg standardnega obnašanja, povezanega z agresijo (npr. grizenje, šavsanje) (Netto in Planta, 1997; Haverbeke in sod., 2009), opazili novo obnašanje, povezano z agresijo. Agresivni psi so prikazali pogostejše mahanje z repom in pogostejšo nagnjenost k mahanju repa v levo. Čeprav nepovezano z agresijo so Quaranta in sod. (2007) opisali, da lahko asimetrično mahanje z repom opazimo med dražljaji z različno čustveno valenco, s pristranskostjo mahanja z repom v desno med pozitivnimi dražljaji in pristranskostjo mahanja z repom v levo med dražljaji, ki jih pes dojema kot negativne. Ker je mahanje z repom v levo pod vplivom desne možganske poloble (Buxton in Goodman, 1967), naša ugotovitev dodatno potrjuje specializacijo desne možganske poloble za izražanje intenzivnih čustev pri psih in drugih živalih (Rogers, 2010; Siniscalchi in sod., 2019).

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~

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ANNEXES

Annex A

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