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Can you spare 15 min? The measurable positive impact of a 15-min petting session on shelter dog well-being

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ABSTRACT

It is well established that human interaction has positive effects on shelter dogs. This work set out to answer the question: "Does one 15-min petting session make a difference for shelter dogs?" Fifty-five dogs were subject to one 15-min petting session with one of five unfamiliar volunteers, in an observation room at a county animal shelter. Volunteers were instructed to interact with dogs in a controlled manner. Sessions were video recorded for later analysis of dog behavior. Saliva was collected before and after the session to assess change in cortisol concentrations. Cardiac activity was monitored throughout the session. Dog response to the interaction session was variable, but generally positive. Dogs were categorized into one of three interaction categories based on the amount of time they spent in actual physical contact with the volunteer: highly engaged (> 75%), moderately engaged (50–75%) or indifferent (< 50%). Generalized Linear Mixed models were used to assess changes in behavior or physiology from beginning (minutes 2 & 3) to end (minutes 14 & 15) of the session and also changes in salivary cortisol concentrations from pre- to post-session. There was no significant change in salivary cortisol concentrations ($P > 0.05$) from pre- to post- session. However, when comparing cardiac activity and behavior from the first two minutes to the last two minutes of the session, dogs had a decrease in heart rate ($P < 0.0001$), an increase in heart rate variability (HF: $P = 0.0006$, RMSSD: $P = 0.0365$, pNN50: $P < 0.0001$) and changes in behavior (decreases in soliciting contact P = 0.0124, standing P = 0.0225) associated with a positive state of relaxation. Given the results of this study it appears that the answer is: "Yes, 15 min does make a positive difference" for many shelter dogs when that time includes close interaction with a person petting and speaking to them in a calm manner.

1. Introduction

It is well documented that human interaction has positive effects on dogs housed in animal shelters including measureable impacts on the dog's physiological state. Human interaction has been shown to be an effective means of reducing stress in shelter dogs as evidenced by reductions in circulating cortisol levels (Hennessy et al., 1998; Coppola et al., 2006; Menor-Campos et al., 2011; Shiverdecker et al., 2013), blood pressure (Odendall and Meintjes, 2003), and positive fluctuations in heart rate variability (Bergamasco et al., 2010).

Most dogs seek contact with humans and, when given the choice between interacting with another dog or a human, they often prefer social interaction and proximity with a human (Tuber et al., 1996). Dogs also express more excitement towards gaining access to a human as compared to another dog (McGowan et al., 2014), and show a reduced stress response to a novel situation in the presence of a human compared to another dog (Tuber et al., 1996). Many dogs show a specific affinity towards petting and will seek out this close contact from both familiar and unfamiliar people (Feuerbacher and Wynne, 2015). Dogs housed in socially restricted environments become more excitable and display stronger indications of aggression and uncertainty (Marston and Bennett, 2003), thus social interaction seems to be important for behavioral health.

Work investigating the impact of human interaction on shelter dog well-being has assessed the impact of repeated sessions involving a mixture of play, petting, soothing tone of voice, grooming, and training on indicators of dog well-being (e.g., Coppola et al., 2006; Valsecchi et al., 2007; Luescher and Medlock, 2008; Menor-Campos et al., 2011). To our knowledge, six studies have examined the impact of petting specifically (Hennessy et al., 1997, 1998, 2002; Shiverdecker et al., 2013; Dudley et al., 2015; Willen et al., 2017). Based on the evidence available, it is reasonable to assume that forms of interaction involving comforting tactile contact with a soothing tone of voice help to diminish a dog's response to stressors experienced in the shelter environment.

While the long-term impact of human interaction on the well-being

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Table 1
Details for dog subjectsincluding: phenotypic description, approximation of age and weight, sex, general descriptor of behavior in kennel and during saliva collection, interaction category for petting session and time spent in shelter. General Behavior: Calm = confident and relaxed; Cautious = unsure about meeting new people and collection procedures; Energetic = bold, high-energy, excitable. Interaction Category (based on% of time in physical contact with volunteer): HE = highly engaged (> 75%); ME = moderately engaged (50–75%); I = indifferent (< 50%).

Dog	Phenotypic Descriptor	Approx. Age (years)	Approx. Weight (kg)	Sex	General Behavior	Interact. Category	Weeks at Shelter
Dickens	Yellow Labrador mix	9.0	31.5	M	Calm	HE	2
Lilly	Chocolate Labrador	0.7	20.0	F	Calm	HE	2
Teddy	Terrier mix	2.0	22.5	M	Cautious	HE	2
Count	Brown & white Pitbull Terrier mix	1.5	22.5	M	Cautious	I	3
Jersey	Black-brindle Labrador-Hound mix	0.5	18.0	M	Cautious	ME	3
Blake	Red & white Amer. Staff. Terrier	2.0	27.0	M	Cautious	I	4
Luke	Yellow Labrador mix	1.5	29.0	M	Energetic	HE	4
Ray	Black & white mixed breed	1.2	27.0	M	Energetic	ME	4
Gus	Hound	1.5	22.5	M	Cautious	HE	5
Bogart	Tri-color Heeler mix	1.0	16.0	M	Energetic	HE	7
Cali	Yellow Labrador mix	6.0	27.0	F	Cautious	ME	7
Dinah	Tan & white Collie mix	3.0	20.0	F	Energetic	HE	7
Gomer	Hound	1.5	22.5	M	Cautious	HE	7
Patti	Tri-color Hound mix	11.0	29.0	F	Cautious	HE	7
Fletch	Black Labrador & Hound mix	0.5	18.0	M	Cautious	ME	8
Moose	Black Labrador mix	1.0	31.5	M	Energetic	HE	8
Scoop	Tri-colored mixed breed	2.0	22.5	M	Calm	HE	8
Charm	Shepherd mix	1.5	16.0	F	Calm	ME	9
Dina	Tan & white mixed breed	3.0	20.0	F	Cautious	ME	9
Ted	Terrier mix	2.0	22.5	M	Cautious	HE	9
Bentley	Black & white Beagle mix	2.0	13.5	M	Energetic	ME	10
Rambo	Black & white mixed breed	1.2	27.0	M	Calm	I	11
Jenny	White & tan Amer. Staff. Terrier	2.0	22.5	F	Calm	I	12
Forest	Black & tan mixed breed	6.0	20.0	M	Calm	HE	13
Ramon	Black & white mixed breed	1.2	27.0	M	Energetic	ME	13
Kailey	Yellow Labrador mix	6.0	27.0	F	Cautious	HE	14
Sundance Kid	Heeler mix	2.0	16.0	M	Cautious	ME	15
Ben	Black & white mix	2.0	13.5	M	Energetic	ME	16
Clifton	Chocolate Labrador	6.0	40.5	M	Energetic	I	22
Maliki	Labrador & Great Dane mix	1.5	31.5	M	Energetic	HE	25
Huntingden	Labrador mix	9.0	27.0	M	Calm	ME	26
Tina	Basenji & Sheba Inu mix	2.0	16.0	F	Cautious	ME	28
Tonya	Black Labrador mix	2.0	29.0	F	Energetic	HE	30
Liddy	Black & tan mixed breed	1.5	13.5	F	Energetic	I	31
Tessa	Black Labrador mix	1.0	18.0	F	Energetic	I	32
Abby	Black & white mixed breed	2.0	22.5	F	Energetic	I	33
Polly	Amer. Staff. Terrier & Boxer mix	2.0	27.0	F	Calm	HE	34
Rusty	Tan mixed breed	1.0	25.0	M	Energetic	I	36
Bali	Black & white mixed breed	1.5	20.0	F	Cautious	I	37
Bathsheba	Black mixed breed	1.5	22.5	F	Cautious	I	38
Molly	Amer. Staff. Terrier & Boxer mix	2.0	27.0	F	Calm	ME	40
Balko	Black & white mixed breed	1.5	20.0	F	Cautious	I	43
Sheba	Black mixed breed	1.5	22.5	F	Cautious	I	44
Durango	Hound mix	1.0	16.0	M	Cautious	I	45
Jackson	Labrador & Pitbull Terrier mix	1.5	27.0	M	Calm	I	45
Amber	Heeler mix	2.0	27.0	F	Calm	HE	47
Bruin	White & red Amer. Staff. Terrier	3.0	22.5	M	Calm	I	49
Rose	Black Labrador	2.0	29.0	F	Energetic	HE	57
Eddie	Chocolate Labrador	3.0	31.5	M	Energetic	ME	64
Kismo	Black Labrador mix	3.5	27.0	M	Energetic	HE	68
Ed	Chocolate Labrador	3.0	27.0	M	Energetic	HE	71
Bon Jour	Brindle mixed breed	3.0	25.0	M	Cautious	ME	78
Zelda	Chocolate Labrador	5.0	40.5	F	Cautious	I	89
Penny	White & tan Amer. Staff. Terrier	2.0	22.5	F	Calm	I	124
Otto	Brown-Brindle mixed breed	4.0	25.0	M	Cautious	I	151

and adoptability of shelter dogs after repeated interaction sessions is well established, to our knowledge, only three studies have looked for behavioral or physiological changes within a single session (i.e., Hennessy et al., 1997; Shiverdecker et al., 2013; Willen et al., 2017). The aforementioned studies examined cortisol and a handful of behaviors (mostly stress related) over a 15–30 min period. Previous research in animal behavior has largely utilized reduction in stress related behaviors or physiology, which are often considered a negative response to a stimulus, for correlative studies. The present study builds upon this existing work by incorporating additional aspects of cardiac activity and a larger suite of behaviors focusing on the interaction between the human and the dog. Specifically, our study aims to focus on positive behavioral and physiological responses to human interaction, a notoriously more challenging approach to assessing how animals perceive a human-induced stimulus.

The aim was to identify measurable differences for dogs within a single interaction session to assess the impact a volunteer visiting a shelter once might have on dogs. Shelter dogs who have been separated from their human companions or have lived as strays show a remarkable demand for social contact with humans which can result in the relatively quick forming of attachments once introduced to new humans (Gacsi et al., 2001). Thus, we hypothesized that even a single session of close human interaction might have a measureable positive impact on shelter dogs. It was predicted that comparisons from the beginning to the end of the session would reveal both positive behavioral and physiological changes indicative of dogs entering a more relaxed state. This work set out to answer the question "Does one 15-min petting session make a positive difference for shelter dogs?"

2. Methods

2.1. Canine subjects

Fifty-five dogs residing at the New Nodaway Humane Society (a county animal shelter) in Maryville, MO, USA between May and August of 2012 were used for this study. Of this group, 23 of the dogs were female and 32 were male (a mix of intact and neutered/spayed). This sex ratio was representative of the population of dogs at this shelter where males outnumber females. The dogs were of various and mixed breeds and, as is typical for most animal shelters, included strays, dogs abandoned or surrendered by their owners, and dogs seized by local authorities for various reasons. Limited information was available on the history of each dog, so no attempt was made to distinguish them based on origin. The dogs were housed in indoor rooms containing banks of kennels. Dogs were housed individually unless they were admitted to the shelter together with a littermate or a companion dog, in which case they were housed in pairs. These housing practices were necessitated by limitations on the size of the kennel runs, local practices for quarantine/observation of the dogs upon admittance to the shelter and behavioral issues with some dogs showing inter-dog aggression. Kennel size was not standardized so depending on the number of dogs housed on any given day, dogs may be moved from single to pair housing when space was available. Selected dogs had been at the shelter for at least two weeks to ensure that, 1) they had, at least to some degree, adjusted to the shelter environment and 2) that they were free from any obvious disease/health condition that might influence their behavior or physiology. Most of the dogs, however, were long-term shelter residents. In addition, to be included in the study, dogs had to weigh at least 12 kg, have slick coats (for best fit of the heart rate (HR) monitor), and not be on any medication that may influence their behavior or hormonal state. All of these dogs were friendly towards people (up at the front of their kennel or would come forward if coaxed with a gentle voice and appeasing posture (e.g., body turned sideways)) and relatively easy to handle by both the volunteers and researchers (all of whom were unfamiliar to the dogs). Admittedly, this selection criteria biased our sample to the dogs that were the most well-adjusted to the shelter environment or who were more friendly or outgoing by nature. However, given the fact that we were putting the dogs in a close contact situation with an unfamiliar volunteer this decision was calculated with the safety of both the dog and volunteer at top of mind. Details for each dog are outlined in Table 1.

2.2. Volunteers

Five volunteers were enlisted to provide the positive interaction with the dogs. This included two female and three male volunteers between the ages of 22 and 27, all of whom had animal experience (with cats or dogs), and had never visited the animal shelter previously.

2.3. Observation room

Dog-volunteer interactions took place in a small observation room just off of the main lobby of the shelter (Fig. 1). The room was empty except for a chair in the corner and a blanket on the floor where the volunteers could sit with the dog during the interaction. A video camera (Sony HDR-XR150, Sony Corporation, Tokyo, Japan) was placed outside of the observation room and all interactions were recorded (for later analysis) through an observation window in the door. Because of the small size of the room and the height of the observation window it was not possible to capture a clear image of the entire room. The

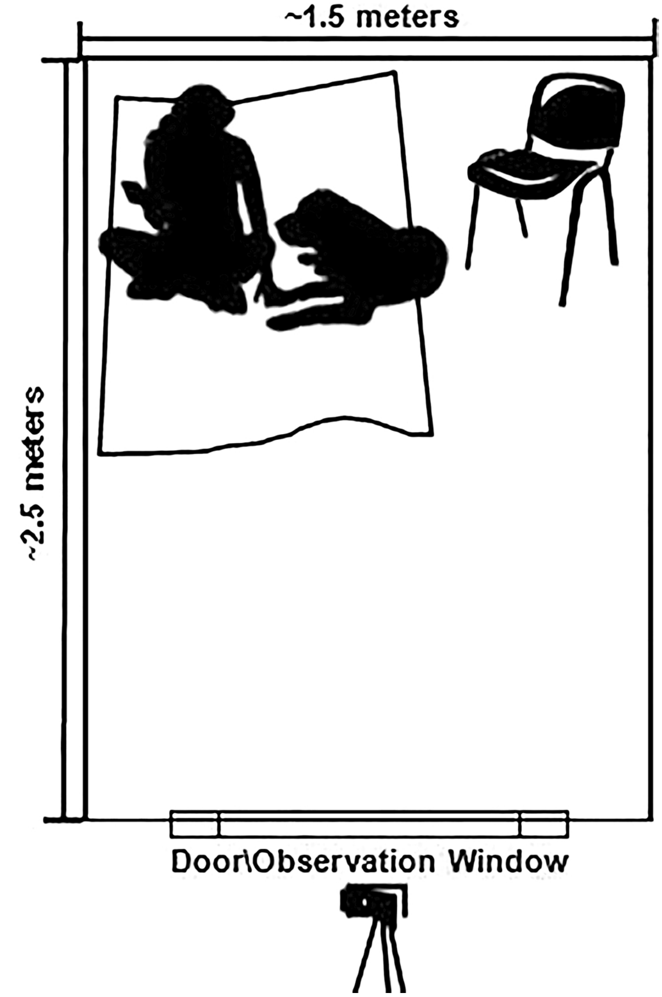

Fig. 1. Diagram of observation room where sessions took place.

camera was focused on the area of the room where the volunteer was sitting, leaving a small area directly under the camera (right against the door) out of view. The observation room functioned as a "meet and greet" space for potential adopters to get to know the dogs at the shelter. Thus, the dogs had different levels of experience with this room, depending on the number of occasions they had been brought out to meet potential adopters. Admittedly, this stands as source of variation between the dogs if these "meet and greet" sessions included calm petting for the dogs by potential adopters. However, given the diverse background of the dogs, and differences in their past experience with people prior to their time at the shelter, this variation is inherently a part of what makes the study mimic the real-life scenario of a volunteer interacting with a dog at the shelter without any knowledge of that dog's previous experiences.

2.4. Test sessions

All dogs were subject to a single 15-min positive one-on-one interaction session with a volunteer as outlined in Table 2. Prior to each session, the dog's date of arrival at the shelter, sex and a rough estimate of his/her age and weight were recorded. Volunteers were instructed to interact with the dogs in an appropriate and standardized manner as outlined in Table 3. In order to standardize the petting styles, all of the volunteers were trained beforehand to ensure consistent positive interactions. The sex of both the dogs and volunteers was accounted for in the experimental design so that, as much as possible, half of the dogs of each sex were petted by a male volunteer and the other half by a female

Table 2
Outline of the test procedure carried out during one 15-min close interaction session between a shelter dog and an unfamiliar volunteer.

Event	Description
Pre-session	Handler collects dog from kennel and walks dog on leash to preparation area where the experimenter collects pre-session saliva sample and fits dog with heart rate monitor. Volunteer sits in observation room awaiting dog's arrival
Introduction	Handler walks dog on leash to observation room to meet volunteer – Volunteer stands with his/her body turned slightly away from dog and lets dog sniff back of his/her hand – Volunteer opens his/her hand with palm facing dog and lets dog sniff his/her hand – Volunteer gently scratches dog under chin and jaw
Initiation	Handler hands leash to volunteer and exits room without interacting with dog (this initiates 15-min session)
Interaction	Volunteer drops leash to allow dog freedom of movement around the room. Depending on behavior and size of dog, volunteer either sits on floor or in chair while interacting with dog. Volunteer does not entice dog to interact, but rather waits for dog to initiate interaction. Volunteer pets and speaks softly to dog when the dog makes contact, alternates petting different areas of dog's body
Post-session	When session is complete, handler and experimenter enter room to collect post-session saliva sample. Heart rate monitor is removed and dog is returned to his/her kennel

Table 3
Outline of the specific interaction criteria provided to the volunteers regarding what was considered appropriate and inappropriate actions during his/her interaction with each unfamiliar shelter dog.

Action	Description
Appropriate Physical Actions	Slow, even strokes along the dog's body Petting from the base of the skull to the base of the tail Scratching behind the ears Scratching at the base of the tail Gently petting the dog's face – over nose, between eyes, under chin Rubbing the dog's ear flaps gently between the thumb and forefinger Petting where the dog seems to enjoy it the most – the dog will relax or "push" this area towards the person Avoid petting areas which appear to be undesirable to the dog (e.g., if the dog pulls away when the area is touched)
Inappropriate Physical Actions	Rapid or hard petting Vigorous scratching Quick, jerky movements
Appropriate Verbal Interactions	Calm, soothing tone of voice Speaking slowly Ignore whining, pet and speak to the dog only when the dog is quiet
Inappropriate Verbal Interactions	High pitched tone of voice Excitable voice

volunteer. Sessions were carried out in the morning between 9:00 and 13:00 h before the shelter opened to the general public.

2.5. Ethical statement

The experiment was conducted according to the USDA guidelines for animal care and use (USDA, 2017). Furthermore, all aspects of the experimental design were approved by the Nestlé Purina Institutional Animal Care and Use Committee.

3. Measures and analyses

3.1. Salivary cortisol concentrations

Saliva samples were collected pre- and post-session to assess changes in salivary cortisol concentrations. An experimenter held Salivettes® (SARSTEDT AG & Co., North Rhine-Westphalia, Nümbrecht,Germany) or surgical eye sponges (bvi Visitec 7 cm Eye Sponge, Beaver-Visitec International Inc., Waltham, MA, USA) in the cheek pocket of the dog encouraging the dog to chew on the device. Salivettes were utilized when dogs had wet mouths and surgical eye sponges were utilized with dogs that had dryer mouths. In addition, food lures (Bennett and Hayssen, 2010) were used to stimulate saliva production by allowing dogs to sniff treats concealed within a closed hand, or sniff an empty treat bag. There is a two-minute window before plasma samples are affected by handling (Broom and Johnson, 1993) and a four-minute window before saliva samples are affected by handling (Kobelt et al., 2003). Conservatively, samples were collected within two minutes of when the dog was approached by the experimenter (prior to placement of the heart rate monitor). After collection, the devices were placed in a plastic double lumen tube and immediately stored in a cooler. Upon return from the shelter (a maximum of 6 h), the samples were centrifuged down (4200 rpm (4105*g*) for 10 min) and transferred to a −80 °C freezer.

For the analysis of cortisol, the saliva samples were thawed and diluted 1:1 with Roche Dilutent Universal (item catalog # 03183971, F. Hoffmann-La Roche AG, Basel, Switzerland). The diluted samples were vortexed to mix the solution and analyzed on the Roche Cobas e411 using the cortisol assay and reagent (item catalog # 11875116160, F. Hoffmann-La Roche AG, Basel, Switzerland). After analysis, the resulting values were multiplied by the dilution factor to get the final values.

3.2. Cardiac activity

Heart rate was monitored continuously throughout the test sessions. Dogs were fitted with a heart rate monitor (Polar Electro, Espoo, Finland) at least five minutes before the initiation of the test session and were removed within five minutes after each test session. Each monitor included a receiver (Polar RS800CX watch) held by the experimenter and a transmitter (Wearlink – soft elastic belt with electrodes imbedded in two sections) worn by the dog. The transmitter belt was flexible and as comfortable for a dog as wearing a harness. A generous amount of contact electrode gel (Spectra 360, Parker Labratories Inc., Fairfield, NJ, USA) was placed under the electrodes in the belt to ensure good contact with the dog's chest (without having to shave any fur). Each heart beat was recorded and mean heart rate, as well as several time and frequency components of heart rate variability were extracted from this using a Polar ProTrainer 5 software package (Polar Electro, Espoo, Finland). Prior to analysis, the raw interbeat intervals were assessed for abnormal beats and artifacts using the automated correction factors in the Polar software package and verified using Kubios HRV Premium inbuilt 'artefact correction' feature (Kubios, Kuopio, Finland) for each dog separately, as normal variability is highly individual. Clean portions of the data (less than 5% correction factor) were used for the analysis.

Mean heart rate at the beginning of the session (minutes 2 & 3) was compared with the mean heart rate at the end of the session (minutes 14 & 15) to assess the changes that occurred. Data from the first minute in the room was not assessed due to the fact that the dogs were usually very active upon initial reaction to entering the room and greeting the

Table 4
Ethogram of dog behaviors used for coding 15-min close interaction session between shelter dogs and an unfamiliar volunteer.

Behavior	Description
Stand	Dog has all four paws in contact with the floor and no other part of his/her body is in contact with the floor, thus the legs are extended. When standing the tail may be held in any position. The dog may be stationary or locomoting.
Sit	Dog is in a stationary position where his/her hind end is on the floor, forepaws are on the floor with the forelimbs straight, such that the body is held in an upright position. When in a sitting position the tail is usually on the ground.
Lie down	Dog's stomach, side or back is in contact with the floor. Limbs may be tucked under or extended depending on the dog's posture. Dog will be stationary.
Solicit play	Solicit play: Dog moves with boisterous, bouncy, exaggerated movements; often in rapid spurts. This may include the following: – Play bow: Dog lowers his/her front end, elbows close to or touching the ground, while keeping his/her back end up – Scamper: Dog runs quickly around room, may slide into a play bow – Bounce: Dog makes vertical movements where at least two paws come up off of the floor
Solicit contact	Dog moves into, rubs, paws at, noses or licks the person. This may include the following: – Lean: Dog makes contact with the person with hips or shoulders, pressing his/her weight against the person – Rub: Dog pushes against the person starting with the dog's neck region and follows with a smear down the dog's body – Paw: Dog places paw on person, may include repeated pawing – Chin: Dog places chin on person, may then look up with eyes to make eye contact with person
In contact	Dog is in contact with the person (any part of its body) of its own accord.
Tail wagging	Dog moves tail from central position (in line with the spine) to either side and back, repeatedly. Duration of wagging recorded. A dog is considered to have stopped wagging if his/her tail is still for at least 5 s.
Tail tucked	Dog tucks tail tightly against his/her body, usually between the legs
Out of sight	Dog is standing up against the door to the observation room out of the line of sight of the camera
Other	The dog is performing any other behavior that does not fall into one of the categories outlined above

volunteer. Visually the dogs seemed to settle and begin interacting with the volunteer within the first minute in the room. Two-minute epoch lengths were analyzed as has been recommended to provide appropriate levels of cardiac data for analysis of both the HF and LF frequencies (Berntson et al., 1997). Measures of heart rate variability specifically influenced by vagal activity from both the frequency and time domains were compared for these time-points. Specifically, HF values (Nickel and Nachreiner, 2003; Oveis et al., 2009) were compared for the frequency domain and RMSSD values (Bogucki and Noszczyk-Nowak, 2015) and pNN50 values (Appelhans and Luecken, 2006) for the time domain.

3.3. Behavior

The behavior of each dog was coded for the entire 15-min session from video by a single trained observer using the Mangold INTERACT 9 video coding system (Mangold International GmbH, Arnstorf, Germany). An ethogram of the behaviors that were coded is outlined in Table 4. Six of the total 55 (11%) videos were chosen at random and double-coded to check intra-rater reliability. The average Cohen's Kappa for all behaviors coded was greater than 0.92. For the analysis of the behavioral data, frequencies (or durations where appropriate) were compared from the beginning of the session (minutes 2 & 3) with frequencies (or durations) from the end of the session (minutes 14 & 15) to assess the changes that occurred during the session.

3.4. Statistical analysis

Descriptive statistics for the frequency and/or duration of each behavior and for all physiological measures are reported as means and standard errors. Generalized Linear Mixed models were conducted to assess changes in behavior or physiology from beginning (minutes 2 & 3) to end (minutes 14 & 15) of the session (with dog included as a random effect to account for correlated data). Generalized Linear Mixed models were conducted as well to assess whether the sex of the volunteer or sex of the dog had any influence on behavioral or physiological parameters at both the beginning and end of the session (with dog as a random effect). Pearson correlations were employed to assess the strength of association between behavioral and physiological measures within these same timeframes. An alpha of 0.05 was used to determine statistical significance for all tests. All analyses were conducted with SAS 9.3 (SAS Institute Inc., Cary, NC, USA).

4. Results

4.1. Dog response

Dogs were variable in their response to a single 15-min session with an unfamiliar volunteer. Based on their overall response to the test situation, dogs were categorized into one of three groups according to the percent of time they spent in actual physical contact with the volunteer over the entire 15-min session. In this way dogs were classified as highly engaged (> 75% of session spent in contact; $n = 20$), moderately engaged (50–75% of session spent in contact; $n = 15$) or indifferent (< 50% of session spent in contact; $n = 20$) to the interaction with the volunteer. Throughout this paper, in addition to the overall results including all dogs as one group, further comparisons are presented with dogs divided into these three interaction categories to demonstrate how these different clusters of dogs were influencing the overall data.

4.2. Salivary cortisol concentrations

There was some difficulty in collecting a sufficient amount of saliva suitable for cortisol analysis for all dogs. Some dogs had relatively dry mouths and, because the subjects were shelter dogs, some had poor oral health/hygiene issues that led to sample contamination (e.g., bleeding gums, coprophagia). Thus there were usable samples from only 32 of the 55 dogs. Overall, post-session (Mean ± SE: 235.43 ± 26.52 μL) saliva samples were greater in volume than pre-session (174.04 ± 20.31 μL) saliva samples ($t_{46} = 2.66$, $p = 0.0107$). While this held true for all three categories of dogs, these differences did not reach statistical significance at the group level and there was only a trend for dogs who were indifferent to interaction ($n = 17$) with the volunteer ($t_{16} = 1.98$, $p = 0.0655$) to show this difference.

Overall, there was no difference between the pre- (Mean ± SE: 0.24 ± 0.03 μg/dl) and post-session (0.22 ± 0.03 μg/dl) salivary cortisol concentrations ($t_{31} = -0.56$, $p = 0.5769$, Fig. 2A). Although not statistically significant, cortisol increased from pre- to post-session for dogs who spent the least amount of time in contact with the volunteer, but decreased for dogs from the other two categories (Fig. 2B). There was no significant impact of the sex of either the dog or the volunteer on volume of saliva or salivary cortisol concentrations.

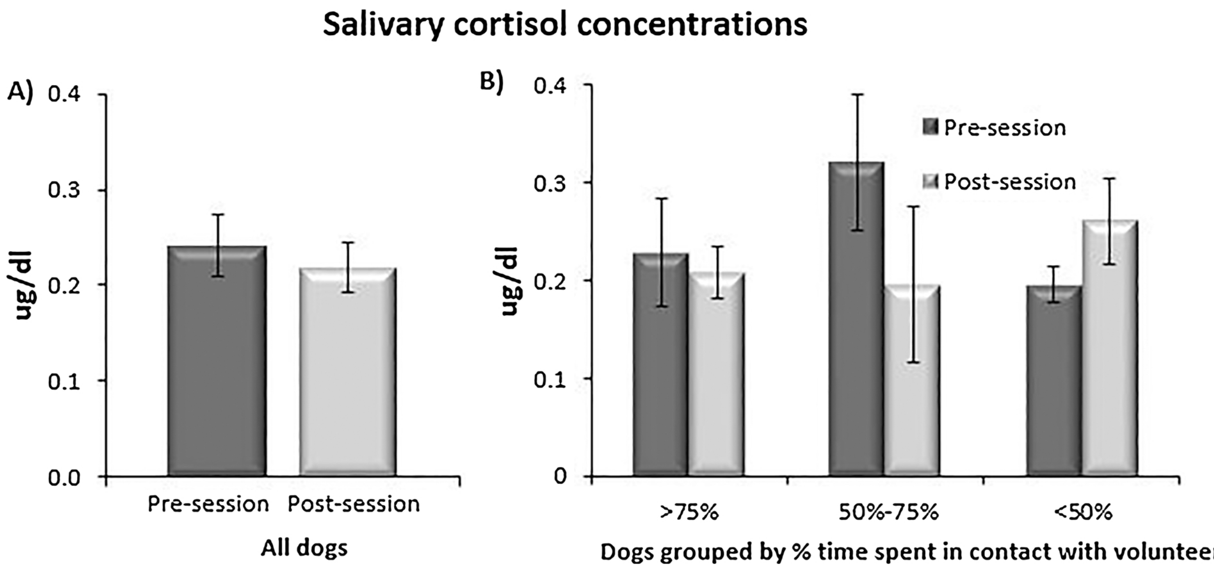

Fig. 2. Pre- and Post-session (Mean ± SE) salivary cortisol concentrations for A) all dogs (n = 32 samples) and B) dogs grouped according to the percent of time that they spent in physical contact with the volunteer (> 75%: n = 15 samples; 50–75%: n = 8 samples; < 50%: n = 9 samples).

4.3. Cardiac activity

4.3.1. Heart rate

There was a change in mean heart rate between the beginning (Mean ± SE: 129.50 ± 4.11 bpm) and the end of the session (112.74 ± 3.41 bpm) with dogs having lower heart rates at the end of the session ($t_{54} = -6.91$, $p < 0.0001$; Fig. 3A). This reduction in heart rate held true for dogs from the highly engaged ($t_{19} = -3.48$, $p = 0.0025$), moderately engaged ($t_{14} = -3.74$, $p = 0.0022$) and indifferent ($t_{19} = -4.65$, $p = 0.0002$) categories (Fig. 3B). There was no significant impact of the sex of either the dog or the volunteer on mean heart rate.

4.3.2. Heart rate variability

Overall, the dogs had higher HF values at the end (Mean ± SE: 1312.85 ± 232.94 ms^2) than at the beginning of the session (546.23 ± 61.06 ms^2; $t_{54} = 3.64$, $p = 0.0006$; Fig. 4A). This increase in HF values was evident for dogs from two interaction categories. Dogs that were highly ($t_{19} = 2.44$, $p = 0.0246$) or moderately ($t_{14} = 2.58$, $p = 0.0218$) engaged showed a marked increase in HF values, however there was only a trend towards a difference for dogs who were indifferent ($t_{19} = 1.99$, $p = 0.0617$) in regards to their interaction with the volunteer (Fig. 4B).

Overall, the dogs had higher pNN50 values at the end (Mean ± SE: 7.69 ± 0.84%) than at the beginning of the session (4.61 ± 0.49%; $t_{54} = 4.39$, $p < 0.0001$; Fig. 5A). At the group level this increase in pNN50 was only significant for dogs that were highly ($t_{19} = 2.48$, $p = 0.0229$) or moderately ($t_{14} = 4.86$, $p = 0.0003$) engaged in the interaction with the volunteer (Fig. 5B) and was not significant for dogs who were indifferent ($t_{19} = 1.51$, $p = 0.1480$) towards the interaction.

As a whole the dogs had higher RMSSD values at the end (Mean ± SE: 65.26 ± 8.65 ms) than at the beginning (46.47 ± 4.10 ms) of the session ($t_{54} = 2.14$, $p = 0.0365$; Fig. 6A). However, this difference was not significant when considering dogs

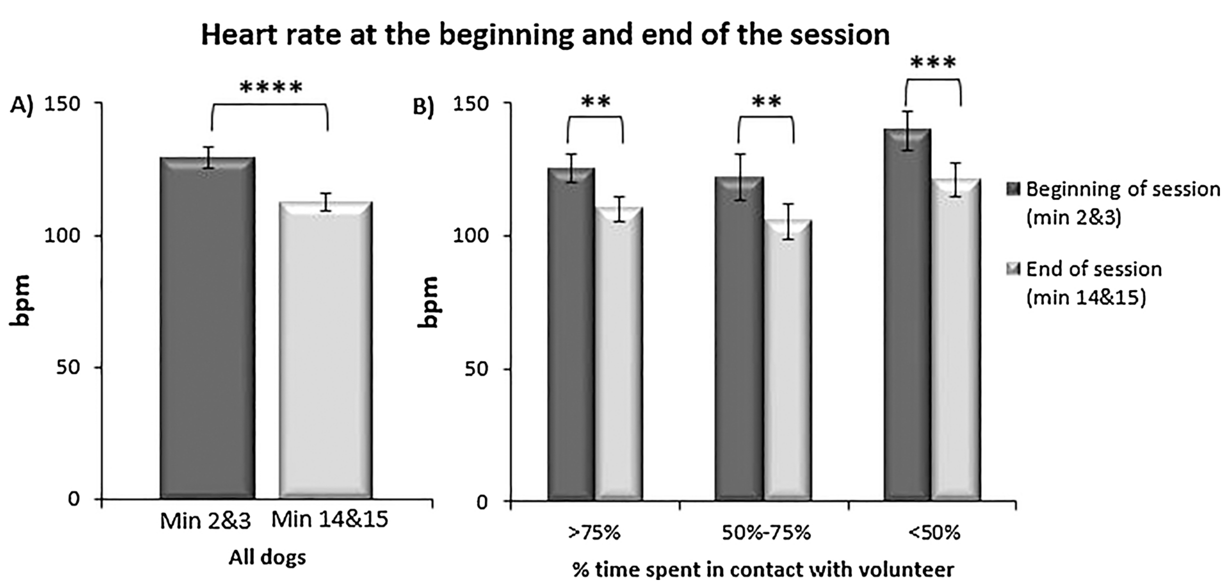

Fig. 3. Change in mean (± SE) heart rate from beginning to end of the 15-min interaction session for A) all dogs (n = 55 dogs) and B) dogs grouped according to the percent of time that they dogs spent in physical contact with the volunteer (> 75%: n = 20 dogs; 50–75%: n = 15 dogs; < 50%: n = 20 dogs). ** $p < 0.01$, *** $p < 0.001$, **** $p < 0.0001$.

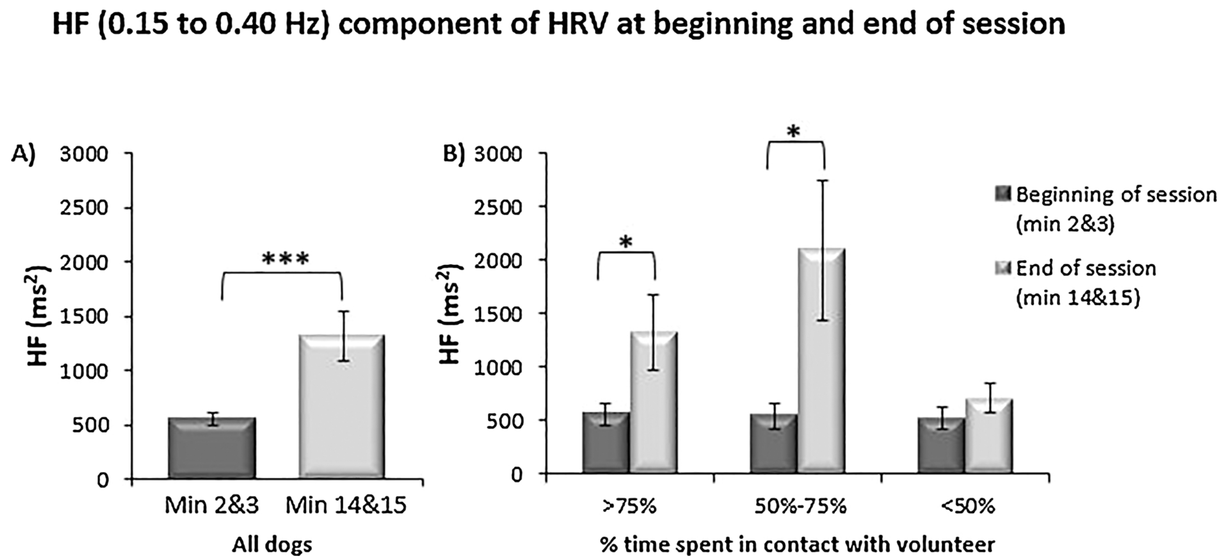

Fig. 4. Mean (± SE) high frequency (HF) component of heart rate variability (HRV) from beginning and end of the 15-min interaction session for A) all dogs (n = 55 dogs) and B) dogs grouped according to the percent of time that they dogs spent in physical contact with the volunteer (> 75%: n = 20 dogs; 50–75%: n = 15 dogs; < 50%: n = 20 dogs). ** $p < 0.01$, *** $p < 0.001$, **** $p < 0.0001$.

from the three interaction categories separately (Fig. 6B). There was no significant impact of the sex of either the dog or volunteer on any component of heart rate variability.

4.4. Behavior

4.4.1. Soliciting contact

Overall, dogs solicited contact from the volunteer more frequently at the beginning (Mean ± SE: 6.64 ± 0.82 solicitations) than at the end (4.45 ± 0.86 solicitations) of the session ($t_{54} = -2.59$, $p = 0.0124$). This decrease in contact solicitation was only evident for dogs that were moderately engaged ($t_{14} = -2.99$, $p = 0.0097$) with a trend towards a difference for dogs who were indifferent ($t_{19} = -1.88$, $p = 0.0760$) to the interaction. By contrast, dogs that were highly engaged in the interaction with the volunteer continued to seek contact at the same frequency at the beginning and end of the session ($t_{19} = -0.13$, $p = 0.8963$). There was no significant impact of the sex of either the dog or the volunteer on soliciting contact.

4.4.2. Soliciting play

Only nine dogs solicited play from the volunteers at the beginning or end of the 15-min session. However for those that did, there was a trend for them to do so more often at the beginning of the session (Mean ± SE: 0.44 ± 0.17 attempts) than at the end of the session (0.15 ± 0.08 attempts). Given the low frequency/incidence of play solicitation this difference did not reach statistical significance ($t_{54} = -1.96$, $p = 0.0550$). This pattern held true for dogs from all three interaction categories. Although the difference did not reach statistical significance, there was a trend towards the sex of the person impacting the solicitation of play on the dogs part ($F_{1,108} = 3.24$,

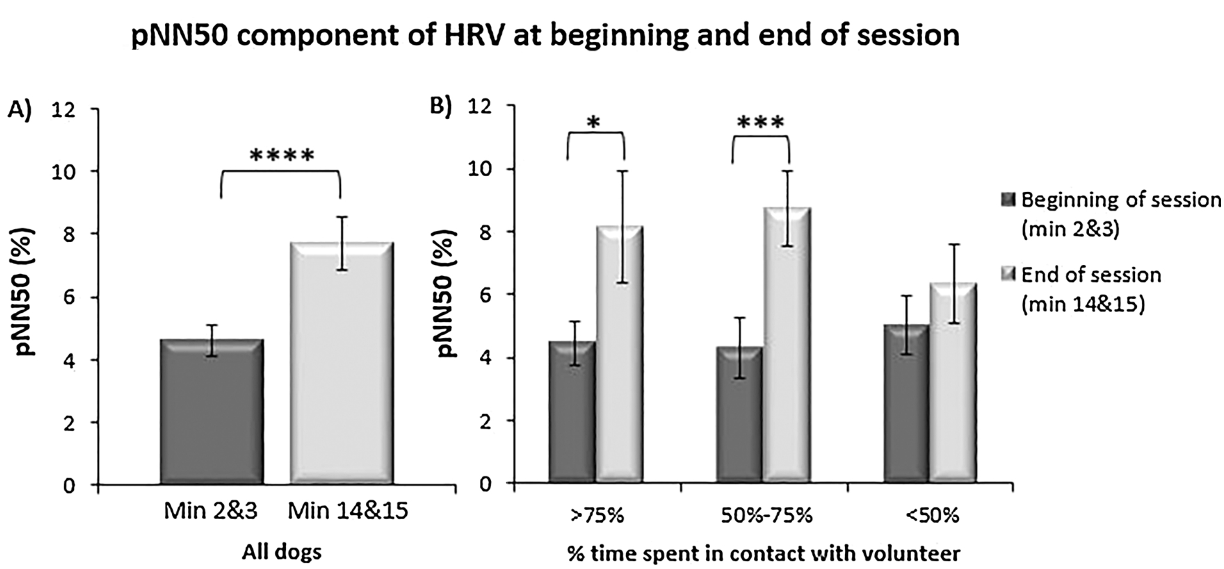

Fig. 5. Mean (± SE) pNN50 component of heart rate variability (HRV) from beginning and end of the 15-min interaction session for A) all dogs (n = 55 dogs) and B) dogs grouped according to the percent of time that they dogs spent in physical contact with the volunteer (> 75%: n = 20 dogs; 50–75%: n = 15 dogs; < 50%: n = 20 dogs). ** $p < 0.01$, *** $p < 0.001$, **** $p < 0.0001$.

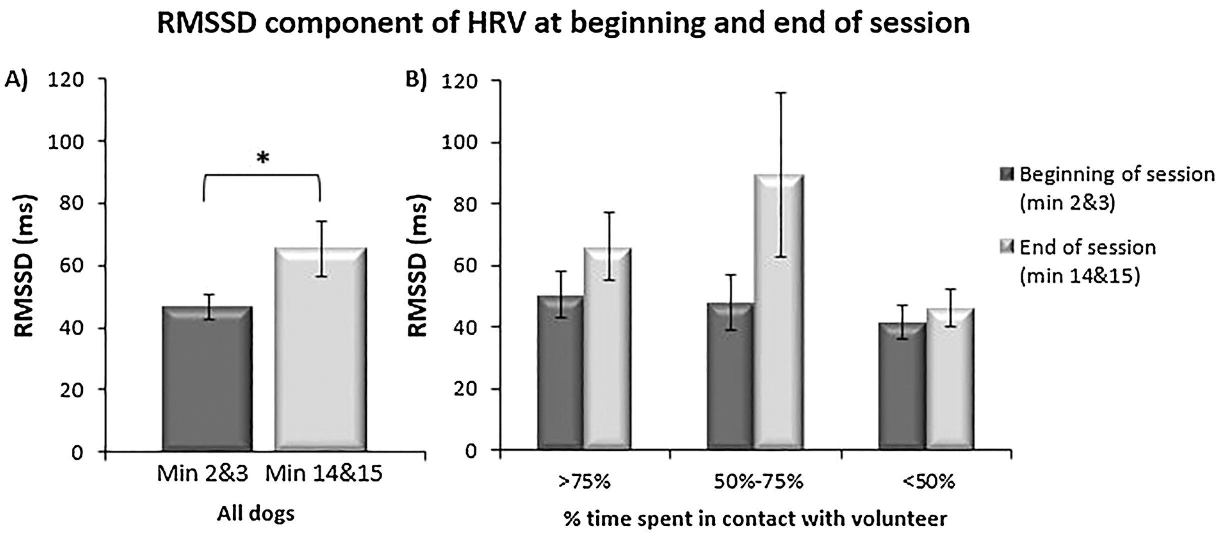

Fig. 6. Mean (± SE) RMSSD component of heart rate variability (HRV) from beginning and end of the 15-min interaction session for A) all dogs (n = 55 dogs) and B) dogs grouped according to the percent of time that they dogs spent in physical contact with the volunteer (> 75%: n = 20 dogs; 50–75%: n = 15 dogs; < 50%: n = 20 dogs). ** $p < 0.01$, *** $p < 0.001$, **** $p < 0.0001$.

$p = 0.0773$) with dogs soliciting play more often from male (0.78 ± 0.31 solicitations) than female (0.27 ± 0.22 solicitations) volunteers.

4.4.3. Tail wagging

Overall, there was no significant change in the frequency (Mean ± SE: 1.75 ± 0.23 and 1.64 ± 0.23 bouts at the beginning and end, respectively; $t_{54} = -0.37$, $p = 0.7155$) or duration (33.51 ± 5.34 and 30.20 ± 4.98 s at the beginning and end, respectively; $t_{54} = -0.62$, $p = 0.5357$) of tail wagging between the beginning and end of the session. For dogs that were moderately engaged with the volunteer, tail wagging bouts were more frequent at the beginning (2.53 ± 0.47 bouts) than at the end (0.93 ± 0.23 bouts) of the session ($t_{14} = -3.43$, $p = 0.0040$). While tail wagging bout frequency was unchanged for dogs that were highly engaged with the volunteer (1.30 ± 0.34 and 1.20 ± 0.28 bouts at the beginning and end, respectively; $t_{19} = -0.28$, $p = 0.7810$), there was a trend towards dogs who were indifferent to wag their tails more at the end (2.60 ± 0.49 bouts) as compared to the beginning (1.60 ± 0.39 bouts) of the session ($t_{19} = 1.84$, $p = 0.0811$). No such differences were apparent when considering the duration of tail wagging bouts. The sex of the volunteer had a significant impact on overall tail wagging behavior ($F_{1,108} = 6.42$, $p = 0.0142$) with dogs wagging their tails more towards female (2.22 ± 0.27 bouts) than male (1.32 ± 0.23 bouts) volunteers ($t_{54} = -2.53$, $p = 0.0142$).

4.4.4. Lying down

Overall, there was no significant difference in the frequency ($t_{54} = 0.26$, $p = 0.7989$) or duration of time ($t_{54} = 1.38$, $p = 0.1734$) dogs spent lying down when comparing the beginning (Mean ± SE: 0.64 ± 0.11 bouts lasting 24.61 ± 5.07 s) to the end (0.67 ± 0.12 bouts lasting 33.63 ± 6.16 s) of the session. This held true for dogs from all three interaction types. There was no significant impact of the sex of either the dog or the volunteer on lying down.

4.4.5. Standing

Overall, dogs spent more time standing at the beginning (Mean ± SE: 66.71 ± 5.63 s) than at the end (52.64 ± 5.82 s) of the session ($t_{54} = -2.35$, $p = 0.0225$), although there was no difference in the frequency of standing events (1.76 ± 0.17 bouts and 1.40 ± 0.17 bouts for the beginning and end, respectively; $t_{54} = -1.51$, $p = 0.1379$). Dogs that spent the least amount of time in contact with the volunteer (indifferent) stood more than the dogs that spent the most time in contact with the volunteer (highly engaged) at both the beginning ($t_{38} = 2.93$, $p = 0.006$) and at the end ($t_{38} = 2.90$, $p = 0.006$) of the 15-min session. There was no significant impact of the sex of either the dog or the volunteer on standing.

4.4.6. Sitting

There was no difference in the frequency ($t_{54} = -0.08$, $p = 0.9328$) or duration ($t_{54} = 1.23$, $p = 0.2235$) dogs spent sitting when comparing the beginning (Mean ± SE: 1.15 ± 0.17 bouts lasting 23.63 ± 4.03 s) to the end (1.13 ± 0.16 bouts lasting 29.18 ± 4.73 s) of the session in general or when looking at dogs from the three different interaction categories. Although, there was a trend towards dogs who were indifferent to the interaction with the volunteer to sit for longer durations at the end (38.98 ± 9.63 s) as compared to the beginning (26.03 ± 7.26 s) of the session ($t_{19} = 1.82$, $p = 0.0842$). The sex of the volunteer had an impact on sitting frequency ($F_{1,108} = 9.52$, $p = 0.0032$) with dogs sitting more often when interacting with male (1.43 ± 0.16 sits) as compared to female (0.68 ± 0.19 sits) volunteers ($t_{54} = 3.09$, $p = 0.0032$).

4.4.7. Out of sight

There was no overall difference in the duration of time dogs spent out of sight of the camera (standing at the exit) when comparing the beginning (Mean ± SE: 7.14 ± 1.47 s) to the end (8.97 ± 2.53 s) of the session ($t_{54} = 0.74$, $p = 0.4633$); however, there was a trend towards dogs being out of sight more frequently at the end of the session (0.78 ± 0.16 bouts) when compared to the beginning (1.04 ± 0.17 bouts) of the session ($t_{54} = -1.88$, $p = 0.0655$). Dogs that spent the least amount of time in contact with the volunteer (indifferent) spent more time out of sight than the dogs who spent the most time in contact with the volunteer (highly engaged) both at the beginning (11.69 ± 3.37 and 2.28 ± 0.87 s for the indifferent and highly engaged dogs, respectively; $t_{22} = 2.70$, $p = 0.01$) and at the end (17.33 ± 6.28 and 1.56 ± 0.94 s for the indifferent and highly engaged dogs, respectively; $t_{20} = 2.48$, $p = 0.02$) of the session. Dogs from the indifferent category were out of sight more often with male (2.11 ± 0.41 occasions) than female (0.86 ± 0.37 occasions) volunteers ($t_{19} = 2.25$, $p = 0.0364$).

4.5. Correlations between behavior and physiology

At the beginning of the session (minutes 2 & 3) there were some weak correlations between behavioral and physiological parameters. Mean heart rate was positively correlated with both the frequency ($r = 0.27$, $p = 0.0486$) and duration of time ($r = 0.29$, $p = 0.0344$) dogs spent wagging their tails. Duration of tail wagging was also negatively correlated with measures of the pNN50 ($r = -0.28$, $p = 0.0354$) and there was a trend towards a negative correlation with both the RMSSD ($r = -0.25$, $p = 0.0610$) and HF ($r = -0.25$, $p = 0.0696$) components of heart rate variability.

At the end of the session (minutes 14 & 15) fewer correlations remained. Mean heart rate was still positively correlated with frequency of tail wagging bouts ($r = 0.28$, $p = 0.0361$) but no longer with the duration of tail wagging ($r = -0.08$, $p = 0.5809$). Whereas duration of tail wagging was negatively correlated with RMSSD at the beginning of the session, by the end of the session it was positively correlated with the RMSSD ($r = 0.30$, $p = 0.0281$) but no longer correlated with the pNN50 ($r = 0.06$, $p = 0.6606$) or HF ($r = 0.22$, $p = 0.1124$) components of heart rate variability.

5. Discussion

The present study set out to answer the question: "Does one 15-min petting session make a positive difference for shelter dogs?" The scope of this project was to address this question specifically in a real shelter environment, thus controls such as monitoring the dog in an empty observation room (no human), or in their kennel environment (unlikely place for a volunteer to sit and interact with a dog) were not included as part of the design. There are already studies (e.g., Tuber et al., 1996; Shiverdecker et al., 2013; Willen et al., 2017) which demonstrate the benefit to dogs of human interaction in a test room over a dog going to a test room alone or the mere presence of a human who is not interacting with them, so these steps were not repeated. Efforts were instead focused on taking a holistic approach combining both behavioral and physiological measures to build upon existing knowledge regarding the impact that a single brief, but close, human interaction session can have on a shelter dog. Both people and dogs benefit from positive interaction with each other and this holds true not just for pets who are closely bonded with their owners, but for dogs at shelters as well (see Pop et al., 2014 for a review). For dogs who previously lived in close contact with humans, their past experiences might underpin the reinforcing properties of social interaction (Feuerbacher and Wynne, 2014). When faced with the challenge of approaching and interacting with an unfamiliar person, shelter dogs, as compared to pet dogs, seek more proximity to the unfamiliar person (Barrera et al., 2010). It has been suggested that shelter dogs might differ in their preference for types of human social interaction and that this could be a reason for their initial relinquishment to a shelter (Feuerbacher and Wynne, 2014) if their social behavior does not match the expectations of their owner. Furthermore, even their adoption from a shelter (Protopopova and Wynne, 2014) could be influenced if they show social behavior that potential adopters find appealing.

Dogs in the present study were variable in how they responded to a single 15-min petting session with an unfamiliar volunteer. Each session was directed by the dog in that the human volunteer did not entice the dog to interact, but rather waited for the dog to initiate interaction following their introduction. Some dogs were eager to interact with the volunteer while others were more hesitant. These differences between dogs most likely highlight distinctions in their underlying temperaments (Jones and Gosling, 2005), coping styles (Horvath et al., 2007), length of time spent in the shelter (Wells et al., 2002), past experiences in the test room and past experiences with people (Horvath et al., 2008; Feuerbacher and Wynne, 2014; Willen et al., 2017). Given that this study was designed to mimic a "real life" situation where volunteers come into a shelter for the first time to interact with dogs from various backgrounds, these differences were considered ideal for addressing the research question at hand. Natural variability of behavior across individuals could have confounding effects on the current study's findings, making it more challenging to derive significant findings. However, individual variation mimics real world settings, and thus provides an applied approach to our question at hand, which was the goal of this study. In the present study three categories of dog naturally emerged based on the time they spent in actual physical contact with the volunteer: 1) highly engaged (spent > 75% of session in contact with the volunteer, 2) moderately engaged (spent 50–75% of session in contact with the volunteer) and 3) indifferent (spent < 50% of session in contact with the volunteer). While the shelter population as a whole showed both physiological and behavioral changes in response to a 15-min petting session with a volunteer, some differences were also apparent between these three categories of dog.

Cortisol has become somewhat of a 'gold standard' for assessing altered physiological states in response to stressful stimuli in most mammals, including dogs (Kobelt et al., 2003), and is considered an important indicator of poor welfare for dogs (Rooney et al., 2007). Changes in cortisol levels, however, are challenging to interpret as cortisol increases with both positive and negative arousal. In other words, cortisol may increase both when a dog is stressed and when a dog is very excited. The variation in the way dogs responded to the 15-min petting sessions with the volunteer, may explain why there were no statistically significant changes in salivary cortisol concentration from pre- to post-session in the present study.

The majority of published studies looking at the impact of human interaction on shelter dogs incorporate some assessment of cortisol, whether it be assessed from saliva (Coppola et al., 2006; Bergamasco et al., 2010), plasma (Hennessy et al., 2006; Shiverdecker et al., 2013) or feces (Uetake et al., 2015). While several of these studies linked human interaction to a reduction in the cortisol response of dogs, others, by contrast, found cortisol to be higher following positive human interaction (see Pop et al., 2014). Furthermore, failure to detect a statistically significant cortisol response is a rather common occurrence, even when subjects seemingly exhibit behavioral signs of stress, and test-retest reliability of acute cortisol response measures is actually rather low (Nicolson, 2007). Take, for example, a study carried out by Odendall and Meintjes (2003) which assessed the response of both people and their dogs during close interaction where the person spoke softly to and petted the dog. Despite finding marked decreases in blood pressure and increases in parameters associated with positive emotional states (e.g., b-endorphin, oxytocin, and dopamine) in both humans and dogs, reductions in circulating cortisol were apparent for the humans but not the dogs. The authors suggested that perhaps this was due to the novel environment in which the experiment took place (Odendall and Meintjes, 2003). In another example, Handlin et al. (2011) found that during positive interaction sessions where circulating oxytocin increased for both humans and dogs, cortisol decreased for humans, but, actually increased for the dogs. In this case, the authors suggested that the rise in cortisol levels might not be related to stress, but rather physical activity (Handlin et al., 2011). Hennessy et al. (2006) found that for shelter dogs enrolled in a prison training program where they were socialized and trained by inmates, cortisol levels were unchanged pre- to post-socialization session. The authors concluded that shelter dogs may suffer from a dysregulation of the hypothalamic-pituitary-adrenal axis (Hennessy et al., 2006). Bergamasco et al. (2010) found no difference in salivary cortisol concentrations between groups of shelter dogs who were or were not subject to a human interaction intervention, but did find some reduction in cortisol within each group following repeated sessions. Similar to the above mentioned studies, in the present study there was some degree of novelty around the test situation (varying levels of familiarity of the observation room for different dogs), the dogs were free to move about the observation room during the 15-min interaction session, and were longer term (greater than two weeks) shelter residents. All of which may have muffled any change in cortisol response that occurred.

Length of stay at the shelter prior to intervention is also an important consideration. For example, Coppola et al. (2006) subjected dogs to human interaction sessions on the second day of being in a shelter and found this treatment to have somewhat of a protective effect on the cortisol levels for the same dogs, compared to dogs that did not experience the interaction, on the third day of being in the shelter. Dogs that were subject to the contact sessions (including play, walks, grooming, training and tactile contact) maintained relatively stable cortisol levels throughout the study, while dogs that did not have this extra interaction experienced elevated cortisol levels on day three (Coppola et al., 2006). Shiverdecker et al. (2013) also monitored dogs as they first entered a shelter, subjecting them to three treatments including the passive presence of a human, a petting procedure or an active play and training session. The authors found a reduction in plasma cortisol concentrations from pre- to post-test in all three conditions, but not for control groups who were not exposed to human presence or interaction (Shiverdecker et al., 2013). It has been shown that glucocorticoid measures are high for dogs for the first few days after entering a shelter environment and then taper off to more normal levels (Hennessy, 2013). As a means to avoid the potential confounding impact of these heightened cortisol levels, the present study focused on dogs that had been at the shelter for a minimum of two weeks. It is important to note that despite their extended stay, the average cortisol level for these dogs was comparable (e.g., Coppola et al., 2006) or higher (e.g., Menor-Campos et al., 2011) than what has been reported previously for newly admitted dogs.

Albeit not statistically significant, there were differences in the cortisol responses of dogs from the three interaction categories that may be biologically relevant. Of interest was the noticeable increase in cortisol for the dogs who spent the least amount of time in contact with the volunteer, which is in contrast to the decrease in cortisol levels for dogs in the other two categories. These findings are in line with those of Horvath et al. (2008) who looked at changes in salivary cortisol levels in response to play sessions between handlers and working dogs (police and border guard dogs). They found that short-term play interaction with the handler did not significantly change cortisol concentrations of the dogs at a population level. However, when making comparisons between groups of dogs with different backgrounds, they found that cortisol could increase or decrease in response to the play session, depending on the type of interaction/experience the dogs had with the person (Horvath et al., 2008). It is also possible in the present study that some dogs may have been, to some degree, stressed by being removed from their kennel, sampled for saliva and fitted with a heart rate monitor. If this were the case, then the changes measured would actually be an assessment of the dog's recovery from this interaction. Every effort was made to ensure that all interactions with the dogs were positive, however this potential limitation should be noted given the diverse background and experiences of shelter dogs.

There is some controversy in the literature over the ideal timing for saliva sampling for analysis of cortisol. Most notably, Vincent and Michell (1992) reported evidence of a delay in the increase of cortisol in saliva compared with blood and, by contrast, Beerda et al. (1996) detected no delay in salivary cortisol responses with respect to plasma responses. It has been suggested (Kobelt et al., 2003) that these differences may arise depending on whether whole serum or plasma concentrations are compared with saliva, as saliva only contains the free fraction of cortisol. The transfer of cortisol from plasma to saliva occurs very rapidly. Within less than a minute, cortisol injected intravenously appears in saliva, and the peak concentration in saliva lags by less than 2–3 min compared to levels measured in the blood (Kirschbaum and Hellhammer, 2000). The advantages of salivary cortisol sampling have been summarized in several reviews (e.g., Kirschbaum and Hellhammer, 1994). In essence the method is preferred by many as it allows for relatively non-invasive sample collection, and salivary cortisol represents the biologically active fraction of the hormone (Vinning et al., 1983; Mendel, 1989). Salivary cortisol is ideal for assessing acute responses to stimuli (Nicolson, 2007). However, salivary cortisol returns to baseline more slowly than blood after psychosocial stressors (Kirschbaum and Hellhammer, 2000) so the ideal timing of samples aimed to detect a decline in cortisol rather than heighted cortisol response after a stressor are not well known. This being said, it is possible that a longer delay in sampling time after the completion of the petting session may have allowed for the detection of a larger reduction in salivary cortisol concentrations. More work in this area is necessary to determine the most appropriate timing for collection of saliva following a positive event (rather than a stressor) for the best assessment of the deactivation (as opposed to activation) of the hypothalamic-pituitary-adrenal axis.

A useful way to better interpret seeming changes in cortisol is to pair this measure with other physiological parameters. In the present study, cardiac activity was monitored throughout the entire session with the analysis focused on changes from the beginning to the end of the session. While it is often difficult to determine the valence of physiological changes, negative emotions are usually characterized by greater physiological activation and positive emotions (at least low arousal ones) are more often characterized by physiological deactivation (Herring et al., 2011). From beginning to end of the 15-min session, in the present study, heart rate consistently decelerated which is typical for a response to low arousal positive (relative to negative) emotions (Ekman et al., 1983). Or at least, it is a strong indication of relaxation as opposed to excitation. This was a significant decrease with the average heart rate dropping by 17 points from the beginning to the end of the 15-min session. This decrease in heart rate aligns with the findings of Bowman et al. (2015), who found a similar response in shelter dogs exposed to classical music in the kennel environment.

Whereas heart rate is influenced by both physical and emotional arousal, heart rate variability is a better indicator for emotional arousal. Greater heart rate variability is indicative of a more relaxed, behaviorally flexible state and has been associated with enhanced cognitive performance and emotional regulation (see Appelhans and Luecken, 2006; Thayer and Lane, 2009; and Thayer et al., 2012 for reviews). Measures of heart rate variability specifically influenced by vagal activity from both the frequency (e.g., HF), and time (e.g., RMSSD) domains have been employed to better understand emotional regulation in humans and a handful of other species including, more recently, dogs (Bergamasco et al., 2010; Kuhne et al., 2014; Bowman et al., 2015; Zupan et al., 2016).

Although measurement and interpretation of HRV are somewhat controversial, it is generally accepted that HF is a specific measure of parasympathetic cardiac control (Berntson et al., 1997; Hughes and Stoney, 2000), mainly due to respiratory sinus arrhythmia (RSA) (Porges, 1995). HF activity has been found to decrease under conditions of acute time pressure, emotional strain and elevated anxiety state (Hughes and Stoney, 2000; Nickel and Nachreiner, 2003) and to increase during positive emotional states (McCraty et al., 1995). In the present study, dogs had higher HF values at the end of the 15-min petting session than they did at the beginning. While it is difficult to make direct comparisons due to differences in experimental design, these findings are in line with those of Bergamasco et al. (2010) who found that dogs undergoing a series of human interaction sessions had higher HF values than a control group who did not take part in such interventions.

It should be mentioned that previous research has found that RSA is associated with long-term tonic (trait-like) rather than short-term (state-like) positive emotionality (Oveis et al., 2009). Therefore RSA was thought not to be a sensitive enough measure to be able to distinguish emotional states during short-term emotion induction. However, this previous work was examining the emotional responses of humans as induced by viewing film clips, which may not have produced a large enough swing in heart rate variability to detect a significant difference. In the present study, dogs were moving from a highly emotionally aroused (when any person entered the kennel the dogs would erupt with excited barking and jumping in anticipation of being retrieved for a walk or time outside), or possibly stressed (for dogs less well adjusted to the shelter environment) to a more relaxed state induced through calm physical interaction. Thus, a larger swing in heart rate variability was predicted for and seemingly achieved in the present study. While the majority of dogs appeared to become more relaxed during the calm interaction session with the volunteer, for those dogs that were less well adjusted to the shelter environment or those who were unsure of interacting with an unfamiliar person, the opposite could also be true. However, from the beginning to the end of the session in the present study, marked changes in HF were detected for the dogs as a whole, with HF values increasing throughout the session.

Valderas et al. (2015) demonstrated that it is possible to differentiate human emotions using HRV analysis, noting that pNN50 values are generally higher for joy than fear. Katayama et al. (2016) drew similar conclusions with dogs pointing towards a decrease in RMSSD values during negative emotional states. Bowman et al. (2015) also utilized HRV analysis to distinguish emotional states in shelter dogs noting increased pNN50 and RMSSD values paired with behavioral signs of stress reduction when dogs were exposed to classical music. The results of the present study are in line with these findings where pNN50 and RMSSD were higher for dogs at the end as compared to the beginning of the 15-min petting session, adding to the mounting evidence that HRV is a useful indicator in identifying different emotional states in dogs.

Interestingly, a recent study by Zupan et al. (2016) suggests that decreases in HF and RMSSD might accompany the presentation of a highly positive stimulus, if dogs are already in a positive emotional state. The authors found HRV to decrease in two situations: 1) when dogs were given a reward compared to the preceding phase where they could only see the reward, and 2) when dogs were given a highly valued reward (meatball) compared to the less highly valued rewards (regular food or interaction with a person). In both cases, it is plausible that the anticipation of the reward was so positive that receiving the reward actually resulted in parasympathetic deactivation by comparison. Previous work in dogs suggests that sometimes anticipation of an event is more positive than the event itself (e.g., Burman et al., 2011) or at least can lead to heightened positive emotional arousal. In the present study both HF and RMSSD values were higher at the end of the 15-min petting session than they were at the beginning of the session. Again, as dogs were moving from a potentially stressful, highly aroused state (in the kennel) to a relatively calm, low arousal state (tranquil one-on-one interaction with a person) this shift towards higher heart rate variability was expected.

There has been a call for the use of ambulatory cardiac monitors to assess changes in both sympathetic and parasympathetic activity throughout the course of “emotionally charged” episodes in “naturalistic settings” (Appelhans and Luecken, 2006). The present study, together with other recent work (e.g., Bergamasco et al., 2010; Bowman et al., 2015), does just this for dogs in a shelter setting. Taken together, the notable decrease in heart rate, increase in the HF values, increase pNN50 values, and increase in RMSSD suggest the dogs were in a more positive/relaxed state towards the end as compared to the beginning of the 15-min session.

Behavioral changes were also evident when comparing the beginning to the end of the interaction session. For dogs that were moderately engaged with the volunteer, tail wagging bouts were more frequent at the beginning than the end of the session. While tail wagging bout frequency was unchanged for dogs that were highly engaged with the volunteer, there was a trend towards dogs who were indifferent wagging their tails more at the end than the beginning of the session. As tail wagging is often used as a form of social solicitation or appeasement, an increase in tail wagging by dogs who were indifferent towards the volunteer would suggest that they were becoming more at ease with the situation. Cardiac activity was loosely correlated with tail wagging behavior. At the beginning of the session mean heart rate was positively correlated with both the frequency and duration of tail wagging. By the end of the session mean heart rate was still positively correlated with the frequency of tail wagging, however no longer with the duration of tail wagging. Kuhne et al. (2014) also noted a correlation between cardiac activity and behavior of dogs that were being petted in a systematic way involving contact with multiple body parts by either familiar or unfamiliar people. They found heart rate increased and heart rate variability decreased for all dogs. At least for the group of dogs interacting with an unfamiliar person, larger changes in heart rate were associated with increased frequency of appeasement gestures in their group of dogs interacting with an unfamiliar person (Kuhne et al., 2014). This differs from the experimental design of the present study, in that the study conducted by Kuhne et al. (2014) the dogs were handled in a systematic way directed by the study protocol (petting defined areas of the body for a defined duration of time), whereas in the present study the interaction was initiated and directed by the dogs. This difference could account for the contrast in results. It is possible that the correlation between tail wagging and heart rate detected in the present study was tied to the physical aspects of moving the tail. Especially as duration of tail wagging was also negatively correlated with some measures of heart rate variability which is in line with the fact that increased physical activity can increase heart rate and decrease heart rate variability. However, if this was the case one would expect the duration of tail wagging to continue to have an influence on heart rate throughout the entire session. The fact that the duration of tail wagging was no longer correlated with heart rate by the end of the 15-min petting session opens up the possibility for speculation that this might be more related to the emotional context (e.g., McGowan et al., 2014) behind the tail wagging, rather than the physicality of it.

During the sessions, volunteers were instructed to interact with the dogs in a very controlled manner; sitting with them while petting and speaking to them in a soothing tone of voice. Despite efforts to standardize the interaction, the sex of the volunteer did have an impact on some behavior expressed by the dogs which is in line with previously reported findings (e.g., Hennessy, 1997; Wells and Hepper, 1999). In the present study, dogs sat more often with male volunteers and wagged their tails more often toward female volunteers. Dogs who were indifferent towards the interaction were out of site (against the door of the observation room) more often with male volunteers than female volunteers. Further investigation into differences in the way that shelter dogs respond to volunteers of different sex is warranted to better understanding the underlying mechanisms here.

It appears that dogs that spent the least amount of time in contact (indifferent) with the volunteer during the session were more likely to solicit play at the beginning of the session than those who spent the most time in contact (highly engaged) with the volunteer. Unfortunately, too few dogs actually solicited play during the sessions to determine if this difference was statistically significant. Interestingly, Protopopova and Wynne (2014) found that a shelter dog’s willingness to play and/or lie in proximity to a potential adopter can have a significant impact on whether the dog is adopted or not. Given the natural breaks in the data of the present study around the amount of time the dogs spent in contact with the volunteer, it would be of interest to follow-up to assess how many of these dogs were successfully adopted and if adoption rate could be linked to these behavioral differences.

6. Conclusions

As predicted, positive physiological and behavioral changes were evident in shelter dogs even after only a single 15-min petting session with an unfamiliar volunteer. A complete understanding of the human-animal bond from the dog's perspective is still in its infancy, however this work contributes to the mounting evidence that humans play an important part in the emotional wellbeing of companion animals. As a result of this study it is clear that: "Yes, 15 min can make a difference" for many shelter dogs when that time includes close interaction with a person petting and speaking to them in a calm manner.

Conflicts of interest

None.

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