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Short-Term Interaction between Dogs and Their Owners: Effects on Oxytocin, Cortisol, Insulin and Heart Rate—An Exploratory Study

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ABSTRACT The aim of this exploratory study was to determine heart rate and the levels of oxytocin, cortisol, and insulin in dogs and their owners in response to a short-term interaction. In addition, the dogs' behavior was studied. The owners' responses were compared with those obtained from a control group. Ten female volunteers and their own male Labrador dogs participated in an experiment during which the owner stroked, petted, and talked with her dog during the first 3 minutes. Blood samples were collected from both dog and owner before (0) and at 1, 3, 5, 15, 30, and 60 minutes after the start of the interaction. Blood samples were analyzed by EIA. Heart rate was monitored telemetrically. The data were analyzed using linear mixed models and paired *t*-tests. The dogs' oxytocin levels were significantly increased 3 minutes after the start of the interaction ($p = 0.027$). Cortisol levels were significantly increased after 15 and 30 minutes ($p = 0.004$ and $p = 0.022$, respectively), and heart rate was significantly decreased after 55 minutes ($p = 0.008$). The dogs displayed normal behaviors during the experiment. The owners' oxytocin levels peaked between 1 and 5 minutes after interaction ($p = 0.026$). No such effect was seen in the controls. Cortisol levels displayed a significant decrease at 15 or 30 minutes in both owners and controls, and insulin levels did so at 60 minutes ($p = 0.030$, $p = 0.002$ and $p = 0.002$,

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$p < 0.0001$, respectively). Heart rate decreased significantly in the owners at 55 and 60 minutes ($p = 0.0008$) but not in the controls. In conclusion, short-term sensory interaction between dogs and their owners influences hormonal levels and heart rate. However, further studies need to be performed in order to better understand the effects of interaction between dogs and their owners.

Keywords: cortisol, heart rate, human–dog interaction, insulin, oxytocin

Human–animal interaction (HAI) has been shown to have positive effects on health and well-being in humans. The acquisition of pets can result in a reduction in health problems and an improvement in perceived health (Serpell 1991). Pet owners have been shown to have lower levels of risk factors for cardiovascular disease, and after acute myocardial infarction, dog owners are significantly less likely to die within 1 year, compared with those who do not own dogs (Friedmann and Thomas 1995). Owning a pet is associated with lower heart rate and blood pressure during basal and stressed conditions (Allen, Shykoff and Izzo 2001; Allen, Blascovich and Mendes 2002). In addition, anxiety decreases in the presence of a dog (Wilson 1991) and children having a dog present in their classroom display increased social competence (Hergovich et al. 2002; Kotrschal and Ortbauer 2003).

The positive health consequences associated with HAI may be caused by oxytocin release induced by positive emotions such as affection and love (Uvnäs-Moberg 1997; 1998) and by the physical interaction that takes place between the human and animal. The physical interaction between humans and dogs involves various types of non-noxious sensory stimulation such as touch, light pressure, warmth, and stroking as well as olfactory, auditory, and visual cues.

Non-noxious sensory stimulation gives rise to physiological effects in *anesthetized* rats; for example, decreased activity in the hypothalamic pituitary adrenal (HPA)-axis and in the sympatho-adrenal system, resulting in decreased cortisol and adrenalin levels and lowered blood pressure. It further increases oxytocin levels and influences the levels of gastrointestinal hormones, as a consequence of efferent vagal nerve activation (Kurosawa et al. 1982; Araki et al. 1984; Stock and Uvnäs-Moberg 1988; Uvnäs-Moberg et al. 1992; Kurosawa et al. 1995). In *unanesthetized* rats, both physiological and behavioral effects are induced by non-noxious sensory stimulation. Stroking of the abdomen (40 strokes/minute for 5 minutes) decreases pulse rate and blood pressure for several hours (Lund et al. 1999), pain thresholds are increased, and a sedative effect is induced. In addition, oxytocin is released (Agren et al. 1995; Uvnäs-Moberg et al. 1996). Repeated exposure to stroking gives rise to long-lasting effects such as an increased pain threshold, decreased blood pressure, and decreased levels of gastrointestinal hormones and energy expenditure, resulting in weight gain (Holst, Uvnäs-Moberg and Petersson 2002; Lund et al. 2002; Holst et al. 2005). Newborn rats subjected to large amounts of non-noxious sensory stimulation in the form of maternal sensory interaction display reduced fear, increased social interaction, and increased function of oxytocin receptors in the amygdala as adults (Liu et al. 1997; Francis et al. 2002).

Similar effects, including decreased cortisol levels, can be observed in humans in response to non-noxious sensory stimulation such as massage, skin-to-skin contact between mothers and infants, and suckling in breastfeeding mothers (Uvnäs-Moberg et al. 1990; Nissen et al. 1996; Uvnäs-Moberg 1996; Uvnäs-Moberg and Eriksson 1996; Handlin et al. 2009). Taken together, these data show that non-noxious sensory stimulation has stress-reducing effects by reducing the activity in the HPA-axis and by decreasing and increasing the activity in certain aspects of the sympathetic and parasympathetic/vagal nervous systems, respectively.

Oxytocin may mediate some of the effects mentioned above by actions in the brain, in particular since some of the effects induced by non-noxious sensory stimulation are reversed following the administration of oxytocin antagonists (Uvnäs-Moberg 1998; Uvnäs-Moberg and Petersson in press). Oxytocin is produced in the supraoptic nucleus (SON) and paraventricular nucleus (PVN) of the hypothalamus and was originally described as a hormone released into the circulation during labor and suckling (Richard, Moos and Freund-Mercier 1991). However, oxytocin is also released into important regulatory areas in the brain from nerves originating in the PVN. Oxytocin stimulates social interactive behavior and promotes attachment between individuals (Carter 1998). Oxytocin also induces, for example, anxiolytic-like effects and sedative effects (Uvnäs-Moberg et al. 1994; Amico et al. 2004), decreases cortisol levels and blood pressure, and influences the release of gastrointestinal hormones, for example, insulin (Petersson et al. 1996; Petersson, Hulting and Uvnäs-Moberg 1999; Petersson et al. 1999; Holst, Uvnäs-Moberg and Petersson 2002).

Since non-noxious sensory stimulation gives rise to a multitude of effects that may in part be mediated by oxytocin in both humans and animals, it is likely that oxytocin release and oxytocin-mediated effects are induced during interaction between humans and dogs. Such effects might explain the health-promoting effects of HAI. This idea is supported by previous studies which show that oxytocin is released in both dogs and humans when they interact physically (Odendaal and Meintjes 2003; Miller et al. 2009).

The aim of this exploratory study was to test the hypothesis that oxytocin release and oxytocin-mediated effects are induced in both dogs and their owners during a short period of interaction characterized by caressing and stroking. To test the hypothesis, oxytocin levels were measured in blood samples collected before, during, and after a short-term interaction between dogs and their owners. Since oxytocin influences the activity of the HPA axis and the autonomic nervous system, cortisol levels were measured to reflect the activity in the HPA axis, and insulin levels were measured to reflect vagal nerve tone. Heart rate was measured to reflect both sympathetic and parasympathetic activity. The dogs' behaviors were analyzed to check that the dogs were well and were not stressed by the experiment.

Methods

Participants

Ten privately owned male Labrador dogs and their female owners were recruited through information provided at local workplaces and local veterinary clinics. The owners were informed about the aim of the study and about the experimental setup. Women older than 30 years who owned a male Labrador older than 1 year were included in the study. Owners and their dogs who participated in the study did not have any illnesses. Ten female volunteers who did not own a dog served as controls. The mean age of the owners and controls was 53 years (*SD* = 10), and 42 years (*SD* = 8), respectively, and the mean age of the dogs was 4.7 years (*SD* = 2.6). There was no significant difference in age between owners and controls. Due to ethical and practical reasons, it was not possible to perform control experiments on the privately owned dogs.

The study was conducted at the Swedish University of Agricultural Sciences in Skara, Sweden. The experimental procedure for the humans was approved by the Local Ethics Committee in Uppsala, and the procedure for the dogs was approved by the Animal Ethics Committee in Uppsala. The use of privately owned dogs was approved by the National Board of Agriculture. Before the experiment started, the owners were once more informed about the

study, were given the opportunity to ask any questions regarding the experiment, and were made aware that they could end their participation at any time. The owner then signed a written consent form for participation in the study for both the dog and herself.

Experimental Setting

The owner and her dog arrived together at the testing facility, which consisted of a plain room containing a desk, four chairs, a bookcase, and a water bowl for the dog. The owners sat in a chair during the entire experiment. In addition, four other people were present in the room during the experiment: an animal caretaker, a nurse, one person taking care of the blood samples, and one person videotaping the experiment. None of these four persons were in contact with the dog or the owner during the experiment except for the animal caretaker and the nurse during the insertion of catheters and sampling of blood.

Preparations

An indwelling catheter was inserted into the cubital vein of the dog owners and the controls. In order to facilitate the insertion of catheters and sampling of blood, the dogs were shaved on the dorsal side of the distal part of a forelimb, where a local anesthetic plaster with prilocaine and lidocaine (EMLA®, AstraZeneca) was attached. The plaster was applied for 45 minutes and then an intravenous catheter was inserted into the cephalic vein. The catheter was covered with Vetrap (CM), in order to prevent the dog from licking it.

The dogs were also shaved on a small area on the lateral side of the chest around which a heart rate monitor (s610i ™, Polar precision performance, Polar Electro) was attached, with the receiver placed a short distance away. The recording range was 30–240 beats/min and the accuracy of the recordings was ± 1 beat/min. In order to maximize contact between the heart rate monitor and the dogs' skin, electrode gel (Blågel, Cefar) was used.

Heart rate monitors of the same type as for the dogs were attached around the chests of the dog owners and the controls, with the receivers placed around their wrists. Heart rate was monitored every 15th second in both dogs and humans. Due to technical problems, heart rate was only measured in five controls.

The Interaction Experiment

Before the experiment started, the owner sat in a chair with her dog unrestrained, sitting or lying beside her. The owner approached her dog at time point zero and started to pet and stroke different parts of the dog's body and talked to him for 3 minutes. The owner was then instructed to remain sitting in her chair and not to touch her dog for the rest of the experiment, which lasted for a total of 60 minutes. If the dog attempted to interact with the owner during the remaining time of the experiment, the owner was instructed to ignore this, with the result that the dog stopped its attempts almost immediately. Verbal communication was allowed during the whole experiment.

The conditions for the control group were the same as for the owners, with the exception that there was no dog present: the participants went through the same preparations, sat in the same chair in the same room with the same people present (except for the animal caretaker), and blood samples were drawn in the same way at the same time points as for the owners.

The goal was to perform all experiments, for the owners and the controls, during the evening, but due to the participants' work schedules, some of the experiments were performed during the morning (4 owners and 5 controls).

Blood Sampling

The first blood samples were taken simultaneously from both the dog and the owner 30 minutes after insertion of the catheter and just before the owner started to interact with her dog (basal = 0 min). Blood samples were then taken from both the dog and the owner at 1, 3, 5, 15, 30, and 60 minutes after the start of the interaction. Insertion of catheters and sampling of blood in the dogs and humans were performed by the same experienced animal caretaker and experienced nurse, respectively.

The blood samples were collected in 4 ml EDTA tubes containing 0.2 ml aprotinin (Trasylol®, Bayer AB). The samples were immediately put on ice and then centrifuged at 1600 × g for 20 minutes at +4ºC after which the plasma was collected and stored at –20ºC, until analysis.

Hormone Analysis

Oxytocin levels were determined in humans and dogs using Correlate-EIA™ Oxytocin Enzyme Immunoassay Kit according to the manufacturer's instructions (Assay Designs, Inc. Ann Arbor, USA) (sensitivity 11.7 pg/ml, precision 9.1%). Cortisol levels were determined using the DSL-10-2000 ACTIVE® Cortisol Enzyme Immunoassay Kit according to the manufacturer's instructions (Diagnostic Systems Laboratories, Inc. Texas, USA) (sensitivity 2.76 nmol/l, precision 10.3%). The dogs' insulin levels were determined using the Mercodia Canine Insulin ELISA 10-1203-1 according to the manufacturer's instructions (Mercodia AB, Uppsala, Sweden) (sensitivity 0.01μg/l, precision 4.6%), and the humans' insulin levels were determined using the Mercodia Insulin ELISA 10-1113-10 according to the manufacturer's instructions (Mercodia AB, Uppsala, Sweden) (sensitivity 1 mU/l, precision 5%). Standards and controls were always included, as recommended by the manufacturers. Before the oxytocin analysis, the samples from the humans were diluted five times in the assay buffer. Before the cortisol analysis, the samples from the dogs were diluted two times in zero standard buffer.

All washing procedures were performed using an Anthos Fluido microplate washer (Anthos Labtec Instruments GmbH), and the absorbance was read using a Multiskan Ex microplate photometer (Thermo Electron Corporation). The color development of the samples was read at 405 nm for oxytocin and at 450 nm for cortisol and insulin, with background correction at 580 nm for oxytocin and 620 nm for cortisol. Ascent software was used for creation of standard curves, curve fitting, and calculation of concentrations (Ascent software ver 2.6 for iEMS Reader MF and multiscan).

One dog was excluded from the oxytocin analysis because his hormone levels were outside the range of detection.

Observations of the Dogs' Behaviors

The entire interaction experiment (60 min) was videotaped, in order to control for how the dogs behaved and experienced the situation. The total time the dog spent sitting, standing, lying down (i.e., both on the chest and on the side), or walking around was recorded. The total time the dog was resting (i.e., put his head on the floor) while lying down, the number of times the dog changed the position of his head while lying down (i.e., when the dog moved his head from left to right or from right to left), and the number of times the dog changed body positions while lying down (i.e., how many times the dog moved his whole body from one side to the other) were recorded. The number of times the dog licked himself around the mouth was also recorded, since this may be an indicator of stress in dogs.

Statistical Analysis

The data were analyzed using SAS version 9.1 for Windows (Cary, NC, USA; 2002) and Statistical Package for the Social Sciences (SPSS/PASW) version 17.0 (Chicago, IL, USA; 2009). Mean values with corresponding standard errors (SE) were used to describe the hormone levels and the heart rate of the dogs, owners, and controls, as well as to describe the different behaviors studied in the dogs.

The distributions of hormone levels for dogs and humans were positively skewed and therefore normalized by logarithmic transformation ($\log_{10}$) before statistical analysis was performed. The heart rate monitors registered the heart rate every 15th second, but only the recordings obtained at each 5th min were used in the statistical analysis.

Sampling time was considered as a categorical predictor and the change in heart rate and hormone levels at specific time points compared with the start of the dog–owner interaction (0 min) was analyzed using linear mixed models in the MIXED procedure of SAS, one model for each trait. For dogs, the models contained sampling time, and the model of cortisol also contained a predictor representing time of day for blood sampling (morning or evening); timing had no significant effect on the other traits and was not included in these models. For humans, the models contained sampling time, a variable representing group (owner or control), and the interaction between time and group; again, the cortisol model contained a predictor for time of day. Correlation between samples within participants was accounted for by a REPEATED statement and, due to the relatively large number of unequally distributed time points for hormones, a compound symmetry correlation structure was applied. Satterthwaite denominator degrees of freedom were specified.

The oxytocin level at 3 min was thus compared with the 0 min level. In contrast, the cortisol levels at 15 and 30 min were compared with 0 min. Likewise, the insulin level at 60 min and heart rate at 55 and 60 min were tested. Time points for comparisons were selected based on previous research and experience, and predicted values (least-squares means) were compared using *t*-tests. P values < 0.05 were considered statistically significant. In dogs, a total of 63, 70, 70, and 129 observations were used in the models of oxytocin, cortisol, insulin, and heart rate, respectively; in humans, 139, 139, 137, and 195 observations were used, respectively. The models were validated by examining the normality of raw residuals.

In a complementary analysis, extreme values of oxytocin and cortisol were considered. The maximum oxytocin level obtained at 1, 3, or 5 min was recorded for each participant. In the same way, the maximum (in dogs) and minimum (in humans) cortisol levels obtained at 15 or 30 minutes were recorded. Again, these time points were chosen based on earlier scientific evidence. Paired t-tests were calculated to test for differences between the extreme values and the basal values.

Results

Hormone levels and heart rate for all participants are presented in Tables 1 and 2. For information about differences between least-squares means at selected time points, standard errors, and p values generated in the linear mixed models, see Table 3.

Dogs

Hormone Levels: The dogs' oxytocin levels were significantly increased 3 min after the start of the dog–owner interaction ($p = 0.027$) (Table 3). In addition, the dogs' peak oxytocin levels recorded at 1, 3, or 5 min were significantly higher compared with the levels collected at time point 0 min ($t = 2.99$; $df = 8$; $p = 0.017$) (Figure 1; Table 1).

Table 1. Hormone concentrations during the interaction experiment, and maximum levels of oxytocin and maximum levels (in case for the dogs) and minimum levels (in case of the humans) of cortisol for the participants (10 male Labrador dogs, 10 female owners, and 10 control persons). Means (*SE*) are shown and are based on non-transformed data.

	0 min	1 min	3 min	5 min	15 min	30 min	60 min	Min/Max Values
					Oxytocin Levels (pmol/l)			
Dogs	155.8 (26.9)	211.2 (30.7)	236.9 (38.7)	178.6 (29.6)	163.5 (34.5)	157.5 (36.0)	157.5 (41.1)	251.8 (34.5) (max)
Owners	168.5 (34.6)	169.8 (34.1)	180.6 (34.4)	170.2 (27.8)	146.4 (34.7)	171.3 (34.2)	165.1 (26.3)	187.0 (33.6) (max)
Controls	208.6 (62.0)	208.2 (64.3)	212.1 (68.2)	212.5 (70.0)	215.6 (68.0)	198.0 (62.9)	212.4 (67.4)	166.1 (43.7) (max)
					Cortisol Levels (nmol/l)			
Dogs	168.4 (14.8)	169.4 (16.1)	168.1 (15.3)	180.1 (17.8)	224.1 (32.5)	202.8 (18.3)	190.2 (18.8)	237.3 (30.3) (max)
Owners	389.8 (119.7)	382.7 (107.4)	382.7 (109.9)	387.6 (119.6)	362.1 (107.9)	331.6 (80.1)	305.2 (62.6)	316.9 (80.5) (min)
Controls	381.5 (30.9)	379.4 (25.9)	375.5 (27.8)	371.9 (28.9)	352.7 (24.2)	332.6 (33.5)	345.5 (37.2)	319.9 (26.5) (min)
					Insulin Levels (pmol/l)			
Dogs	37.5 (7.8)	32.6 (5.4)	28.5 (3.4)	30.8 (3.8)	34.6 (8.9)	32.4 (6.7)	42.9 (8.6)	–
Owners	159.6 (42.5)	149.0 (36.8)	142.5 (31.7)	151.8 (38.8)	142.2 (53.9)	126.8 (44.4)	101.4 (35.2)	–
Controls	155.2 (67.6)	159.4 (68.4)	154.7 (58.4)	148.1 (48.7)	159.0 (44.9)	114.1 (42.3)	51.4 (32.7)	–

The dogs' mean cortisol levels exhibited a delayed and protracted rise, and cortisol levels were significantly increased after 15 and 30 min after the start of the dog–owner interaction, when compared with levels obtained before the interaction started ($p = 0.004$ and $p = 0.022$, respectively) (Table 3). A significant peak in the dogs' cortisol levels during the same time period could not be demonstrated with the paired *t*-test ($p = 0.146$) (Figure 2; Table 1). The levels of cortisol were 41% higher in the morning than in the evening ($p = 0.048$).

Insulin levels did not change significantly during the experiment (Figure 3; Tables 1 and 3).

Heart Rate: There was a significant decrease in the dogs' heart rate at 55 min compared with at the start of the interaction ($p = 0.008$). In contrast, there was no significant change at 60 min (Figure 4; Tables 2 and 3).

Behavioral Observations: These were made from the videotapes and the results are summarized in Table 4. The dogs displayed normal behaviors during the experiment. They walked around for a short while but were mostly resting.

Table 2. Heart rate (beats/min) during the interaction experiment for the participants (10 male Labrador dogs, 10 female owners, and 10 control persons). Mean (*SE*) values are shown and are based on non-transformed data.

	0 min	5 min	10 min	15 min	20 min	25 min	30 min	35 min	40 min	45 min	50 min	55 min	60 min
Dogs	94 (11)	94 (8)	83 (9)	88 (9)	84 (9)	67 (7)	75 (3)	88 (10)	87 (14)	82 (15)	80 (15)	67 (8)	76 (4, 2)
Owners	78 (5)	78 (5)	78 (4)	76 (4)	74 (4)	74 (4)	74 (4)	71 (4)	72 (3)	71 (3)	72 (4)	71 (4)	71 (4)
Controls	74 (6)	68 (5)	70 (5)	70 (5)	72 (6)	68 (6)	70 (5)	72 (6)	73 (6)	70 (5)	73 (3)	71 (6)	71 (4)

Table 3. Back-transformed least-squares means (LSM) at start of dog–owner interaction (0 min) and at selected time points, standard errors (*SE*), and *p* values generated from the linear mixed models of hormone levels and heart rate.

Trait and Time Point	LSM	*SE*	*p*
Dogs			
Oxytocin at 0 and 3 min (pmol/l)	139.5; 210.1	1.20	0.027
Cortisol at 0 and 15 min (nmol/l)	162.2; 205.1	1.08	0.004
Cortisol at 0 and 30 min (nmol/l)	162.2; 195.0	1.08	0.022
Insulin at 0 and 60 min (pmol/l)	32.4; 31.4	1.22	0.882
Heart rate at 0 and 55 min (beats/min)	94.2; 66.9	10.02	0.008
Heart rate at 0 and 60 min (beats/min)	94.2; 83.1	10.32	0.283
Owners			
Oxytocin at 0 and 3 min (pmol/l)	147.2; 160.3	1.07	0.191
Cortisol at 0 and 15 min (nmol/l)	297; 263.5	1.06	0.055
Cortisol at 0 and 30 min (nmol/l)	297; 271.6	1.06	0.136
Insulin at 0 and 60 min (pmol/l)	129.5; 69.8	1.21	0.002
Heart rate at 0 and 55 min (beats/min)	78.1; 71.4	1.96	0.0008
Heart rate at 0 and 60 min (beats/min)	78.1; 71.4	1.96	0.0008
Controls			
Oxytocin at 0 and 3 min (pmol/l)	159.2; 155.2	1.07	0.697
Cortisol at 0 and 15 min (nmol/l)	369.0; 345.1	1.06	0.266
Cortisol at 0 and 30 min (nmol/l)	369.0; 318.4	1.06	0.015
Insulin at 0 and 60 min (pmol/l)	84.4; 28.4	1.23	< 0.0001
Heart rate at 0 and 55 min (beats/min)	73.8; 71.2	2.77	0.350
Heart rate at 0 and 60 min (beats/min)	73.8; 71.0	2.77	0.314

Dog Owners and Controls

Hormone Levels: Neither owners nor controls showed a significant change in oxytocin levels after 3 min of dog–owner interaction (Table 3). However, the owners' peak oxytocin levels recorded at 1, 3, or 5 min were significantly higher compared with the levels collected at time point 0 min ($t = 2.66$; $df = 9$; $p = 0.026$). Such an effect was not seen in the controls ($p = 0.417$) (Figure1; Tables 1 and 3).

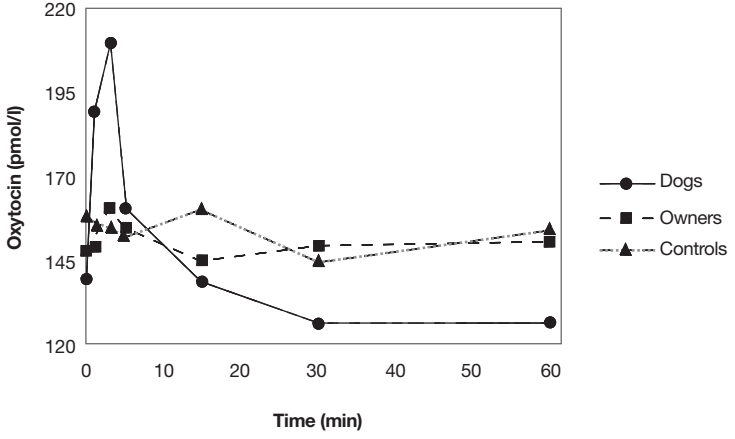

Figure 1. Predicted levels of oxytocin (pmol/l) in 10 male Labrador dogs, 10 female owners, and 10 female control persons; back-transformed least-squares means from a linear mixed model. The first blood sample was taken immediately before the owner started to interact with her dog (0 min) and other samples were taken 1, 3, 5, 15, 30, and 60 min later. Standard errors for oxytocin levels at 0 and 3 minutes in dogs = 1.2, in owners = 1.22, and in controls = 1.22.

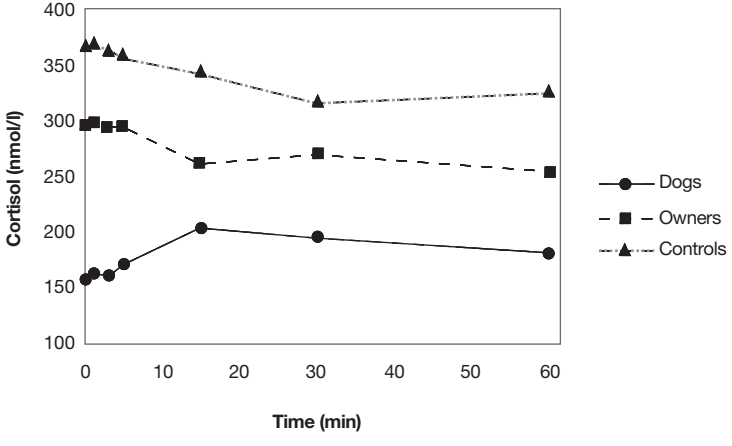

Figure 2. Predicted levels of cortisol (nmol/l) in 10 male Labrador dogs, 10 female owners, and 10 female control persons; back-transformed least-squares means from a linear mixed model. The first blood sample was taken immediately before the owner started to interact with her dog (0 min) and other samples were taken 1, 3, 5, 15, 30, and 60 min later. Standard errors for cortisol levels at 0, 15 and 30 minutes in dogs = 1.1, in owners = 1.18, and in controls = 1.18.

The owners' cortisol levels tended to be decreased at 15 min after the start of the interaction with the dog ($p = 0.055$) but not at 30 min ($p = 0.14$) (Table 3). Their minimum cortisol

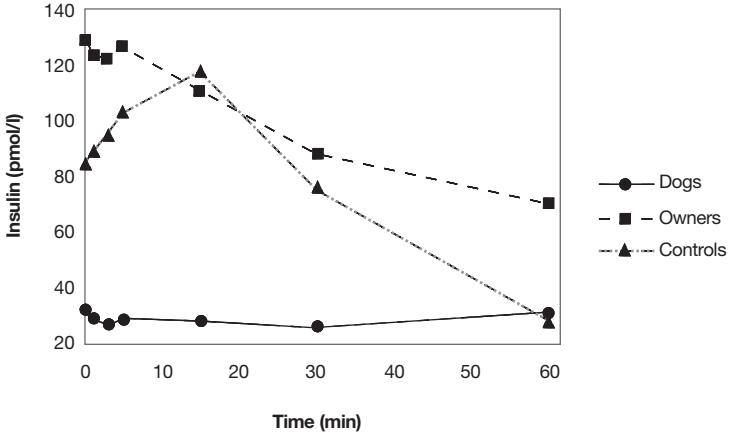

Figure 3. Predicted levels of insulin (pmol/l) in 10 male Labrador dogs, 10 female owners, and 10 female control persons; back-transformed least-squares means from a linear mixed model. The first blood sample was taken immediately before the owner started to interact with her dog (0 min) and other samples were taken 1, 3, 5, 15, 30, and 60 min later. Standard errors for insulin levels at 0 and 60 minutes in dogs = 1.22, in owners = 1.03, and in controls = 1.03.

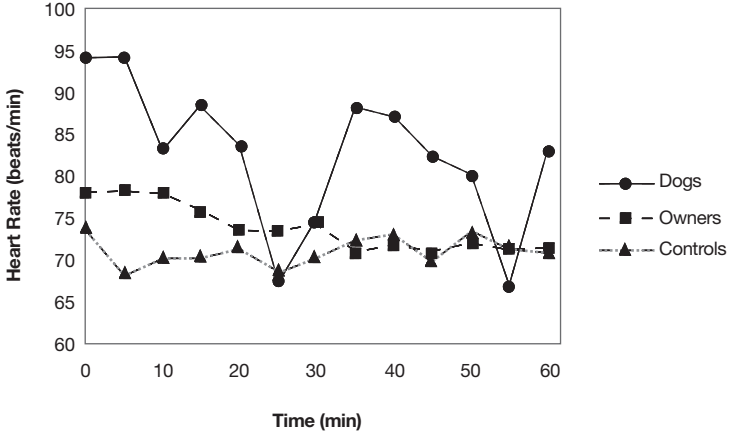

Figure 4. Predicted levels of heart rate (beats/min) in 10 male Labrador dogs, 10 female owners, and 10 female control persons; least-squares means from a linear mixed model. Standard errors at 0, 55, and 60 minutes in dogs = 10.08, in owners = 4.00, and in controls = 5.66.

levels reached at 15 or 30 min were significantly decreased compared with the levels collected at time point 0 min ($t = –2.573$; $df = 9$; $p = 0.030$) (Figure 2; Table 1).

The controls did not display a significant decrease in cortisol levels at 15 min ($p = 0.266$), but did so at 30 min ($p = 0.015$) (Table 1). In addition, their minimum cortisol levels recorded at 15 or 30 min were significantly decreased compared with the levels collected at time point

Table 4. Behavior of 10 male Labrador dogs during 60 min of human interaction; means and their standard errors (*SE*).

Behavior	Mean (*SE*)
Total time sitting (min:sec)	4:30 (1:24)
Total time standing (min:sec)	2:00 (0:42)
Total time lying down (min:sec)	52:00 (2:00)
Total time walking around (min:sec)	2:00 (0:36)
Total time resting while lying down (min:sec)	30:00 (4:14)
Licking around mouth (number of times)	44 (13)
Position changes of the head while lying down (number of times)	27 (4)
Position changes total (number of times)	17 (4)

0 min ($t = –4.275$; $df = 9$; $p = 0.002$) (Figure 2; Table 1). The levels of cortisol for both owners and controls were 80% higher in the morning than in the evening ($p = 0.010$).

In both owners and controls, there was a significant decrease in insulin levels at 60 min ($p = 0.0018$ and $p < 0.001$, respectively) (Figure 3; Table 3).

Heart Rate: Heart rate was significantly decreased at 55 and 60 min in the owners ($p = 0.0008$ and $p = 0.0008$, respectively). In contrast, no change in heart rate was seen in the controls (Figure 4; Table 3).

Differences between Owners and Controls Over Time

There was a significant statistical interaction between time and group for insulin and heart rate ($p = 0.045$ and $p = 0.011$, respectively) but not for oxytocin and cortisol ($p = 0.650$ and $p = 0.906$, respectively).

Discussion

The aim of this exploratory study was to test the hypothesis that oxytocin release and oxytocin-mediated effects are induced in both dogs and their owners in response to physical interaction. The results show that short-term interaction between a dog and its owner is associated with a significant increase in oxytocin and cortisol levels in the dog. In addition, oxytocin increased significantly in the owners but not in the controls, cortisol and insulin levels decreased in both the owners and the controls, while heart rate decreased significantly only in the owners. To our knowledge, the present study is unique since it was performed under standardized conditions with an equal focus on the humans and dogs, and repeated observations were made before, during, and after interaction between the dog and its owner.

We chose to study male Labrador dogs and their female owners in order to keep variation due to breed and sex steroid levels to a minimum. In addition, Labradors are one of the most common companion dogs and are friendly and prone to interaction with humans, which is advantageous when studying human–animal interaction

In a previous study performed by Odendaal and Meintjes in 2003, some effects were noted in response to interaction between dogs and humans. The levels of β-endorphin, oxytocin, prolactin, phenyl acetic acid, and dopamine all increased in the dogs and humans after interaction, whereas cortisol increased in the dogs and decreased in the humans (Odendaal and Meintjes 2003). Although the results from that study display effects of interaction, the differences between it and our study regarding participants, experimental layout (only two blood

samples collected before interaction and one collected between 4 and 24 minutes versus repeated blood samples collected at different time points during the experiment), and different methods for analyzing hormone levels (yielding extremely different hormone levels) makes further comparisons difficult.

Recently, Miller et al. (2009) showed that women increase their oxytocin levels significantly after interaction with their own dog. However, the same response was not observed in men. That study focused only on humans, and only pre- and post observations were made (Miller et al. 2009).

Nagasawa et al. (2009) reported increased oxytocin levels in the urine of humans in response to gaze and touch (Nagasawa et al 2009). However, the relationship between oxytocin levels in plasma, which mainly reflect oxytocin release from the pituitary, and oxytocin detected in urine is at present unclear (Uvnäs-Moberg, Handlin and Petersson 2011).

Touch and massage-like stroking of rats and close physical contact in humans increases oxytocin levels (Stock and Uvnäs-Moberg 1988; Nissen et al. 1995; Lund et al. 2002). Against this background, it is likely that the distinct and short-lasting rise of oxytocin levels in the dogs and the increased peak levels in the owners during our experiment were caused by the stroking and petting performed by the owner.

In addition, non-noxious sensory stimulation induces stress-reducing effects in many different species. Rats being stroked on the abdomen show decreased blood pressure (Lund et al. 1999). Cows being brushed on the abdomen show decreased heart rate and cortisol levels (E. Wredle, personal communication). Skin-to-skin contact between mother and infant induces lowering of blood pressure and cortisol levels in mothers and decreases cortisol levels and increases cutaneous circulation in the infants (Nissen et al 1996; Uvnäs-Moberg 1996; Uvnäs-Moberg and Eriksson 1996; Morelius, Theodorsson and Nelson 2005; Jonas et al. 2008; Handlin et al. 2009). Further, the levels of gastrointestinal hormones, including insulin, are also influenced by stroking (Uvnäs-Moberg et al. 1992; Holst et al. 2005).

Since oxytocin is released by sensory stimulation, the interaction between the dogs and owners may have decreased cortisol levels and heart rate via oxytocin released into the brain. During the interaction experiment, though, the dogs displayed an increase in cortisol levels. A rise in cortisol levels is often connected with high stress levels. It may, however, also reflect initiation of physical activity. In the present experiment, the dogs were behaviorally activated in response to the interaction. Since cortisol levels in the circulation rise with a 15 to 20 min delay, we suggest that the increase in the dogs' cortisol levels reflect an increase in the locomotor activity induced by the interaction with the owner. The increase was not confirmed by the complementary paired *t*-test of maximum values at 15 or 30 min, which is probably explained by the small number of participants.

The expected fall in insulin levels normally induced by sensory stimulation was not observed in the present study. The owners were instructed not to feed their dogs just before arriving at the testing facility. However, it turned out that some dogs had received food just before arriving. A different pattern of insulin levels might have been obtained if all dogs had either been fasted or fed before the start of the experiment, since feeding influences insulin levels.

The dogs' heart rate was significantly decreased after 55 but not after 60 minutes. Oxytocin induces, via effects in the brain, a decrease in sympathetic and an increase in parasympathetic nervous tone. These changes influence cardiovascular function and hence oxytocin released in the brain may have contributed to the temporary decrease in heart rate observed. The reason for not seeing a significant decrease also after 60 minutes is probably due to the fact that

a blood sample was collected at this time point, which may have resulted in a slight activation of the sympathetic nervous system.

It is clear that the response in dogs to dog–owner interaction is complex and involves endocrine and physiological reactions reflecting both activation and relaxation. In the present study, the interaction experiment was performed in an unfamiliar room. However, the time that had elapsed from entering the room until the start of the experiment gave the dogs time to adjust to the unfamiliar surroundings. The results from the behavior analysis indicated that the dogs displayed normal behavior and therefore they seemed to tolerate the experimental situation well.

The owners' oxytocin levels peaked between 1 and 5 min after interaction. This was not seen in the controls. These data confirm the results of Miller et al. (2009) and Odendaal and Meintjes (2003). The design of the present experiment, allowing the owner to be in the same room as the dog as well as being aware of the interaction before it started, might explain why the rise in circulating oxytocin levels occurred at different time points.

Both owners and controls displayed decreased cortisol levels over time. Perhaps the experimental situation, involving blood sampling, was perceived as stressful, which might have caused a rise in cortisol levels in both groups, and then a decrease over time in both.

In addition, insulin levels fell over time in both owners and controls. Since feeding was not controlled for, any effects caused by the sensory interaction in the owners might have been concealed by parallel feeding-related changes in glucose and insulin levels.

The observation that the owners' heart rate decreased significantly suggests that interaction with the dog might have induced a slight anti-stress effect in the owners. This effect may be a consequence of the oxytocin released in the brain caused by the sensory interaction. This finding may be of great importance, since it may be easier to demonstrate a decreased activity in the sympathetic nervous system than in the HPA-axis as a consequence of (sensory) interaction.

The ambition was to perform all experiments, for the owners and the controls, during the evening, but due to the participants' work schedules' some of the experiments were performed during the morning (4 owners and 5 controls). Oxytocin and insulin are not known to have circadian rhythms, and hence the results for these hormones are not likely to have been affected by the experiment being conducted at different times of day. In contrast, cortisol has a circadian rhythm, with levels being highest in the morning and decreasing throughout the day (Arlt and Stewart 2005). In line with this, cortisol levels were significantly higher in the morning than in the afternoon in both humans and dogs.

Our results show that there is a release of oxytocin and that some oxytocin-mediated effects can be observed in dogs and their owners when they interact with each other. Since this is an exploratory study with only 10 dog–owner pairs participating, the results need to be interpreted with caution and further studies need to be performed with a larger number of participants and under even more standardized conditions. This will facilitate better recording and understanding of the physiological and behavioral responses in dogs and their owners as a consequence of interaction. In addition, it would be interesting to study the consequences of interaction between both female and male dogs and female and male owners, as well as interaction with dogs and an unfamiliar person.

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