



Dog's gaze at its owner increases owner's urinary oxytocin during social interaction

Miho Nagasawa^a, Takefumi Kikusui^{a,*}, Tatsushi Onaka^b, Mitsuaki Ohta^a

^a Department of Animal Science and Biotechnology, Azabu University, 1-17-71 Fuchinobe, Sagami-hara, Kanagawa-ken 229-8501, Japan

^b Department of Physiology, Jichi Medical University, Minamikawachi-machi, Tochigi-ken, 329-0498, Japan

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ABSTRACT

Oxytocin (OT) has been shown to play an important role in social bonding in animals. However, it is unclear whether OT is related to inter-species social bonding. In this study, to examine the possibility that urinary OT concentrations of owners were increased by their “dog's gaze”, perhaps representing social attachment to their owners, we measured urinary OT concentrations of owners before and after interaction with their dogs. Dog owners interacted with their dogs as usual for 30 min (interaction experiment) or were instructed not to look at their dogs directly (control experiment). We observed the behaviors of owners and their dogs during the experiments, and measured OT concentrations by radioimmunoassay in urine samples from the owners collected just before and 20 min after interaction with their dogs. Using a cluster analysis, owners could be divided into two groups: one received a longer duration of gaze from their dogs and reported a higher degree of relationship with their dogs (LG); the other received a shorter duration of gaze and reported a lower degree of relationship (SG). Urinary OT was higher in LG than SG after usual interaction with their dogs, but not in the control experiment. In the interaction experiment, a high correlation was found in LG between the frequency of behavioral exchanges initiated by the dog's gaze and the increase in urinary OT. We conclude that interactions with dogs, especially those initiated by the dog's gaze, can increase the urinary OT concentrations of their owners as a manifestation of attachment behavior.

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Introduction

Dogs, *Canis familiaris*, were domesticated at least 14,000 years ago (Nobis, 1979) and have assumed a variety of roles in the lives of humans, acting as shepherds, security guards, partners in different activities, assistants for disabled people, and companions. It is suggested that dogs have been selected inadvertently during the process of the domestication for tameness and to be neither aggressive towards nor fearful of humans (Coppinger and Schneider, 1995). It is thought that during this process dogs have evolved similar social-communicative cognitive abilities to those of human beings (Hare et al., 2002; Hare and Tomasello, 2005). Dogs may have acquired a cognitive ability superior to that of wolves and apes for understanding human pointing or gaze cues, and they show similar visual behavior to humans (Hare et al., 2002; Miklósi et al., 2003). Such abilities of dogs enable them to exhibit behavior that is highly coordinated with that of humans.

Visual cognitive ability, especially “gaze”, is the most fundamental and important manifestation of social attachment between a human mother and infant (Dickstein et al., 1984). In human infants, attachment behaviors such as “cry,” “smile,” and “gaze” are observed to attract their caregiver to them, instead of moving towards the

caregiver. The gaze that an infant sends to the caregiver is considered to be a semiautomatic attachment behavior. The infant's gaze is interpreted by caregivers as a signal with a purpose (Meins, 1997) and results in the proximity of caregivers. Thus, gaze works successfully as an attachment behavior in humans.

On the other hand, dogs innately show behavior that leads them to approach humans. Even punishment by handlers does not extinguish the proximity of puppies to the handler (Fisher, 1955; Bowlby, 1969), and this resembles the relationship between mothers and infants of various species, including rats, monkeys, and humans. Separation distress in puppies is greatly reduced when a human is nearby (Pettijohn et al., 1977). Topál et al. (1998) also reported that adult dogs show similar behavior to human infants in separation from and reunion with their owners. Adult shelter dogs have been shown to form an attachment to humans within a short period (Gácsi et al., 2001). Meanwhile, according to the survey of American Animal Hospital Association, 75% of pet owner consider their animals akin to children (Serpell, 2003). Humans are apt to consider their dogs as child substitutes (Collis, 1995). It is said that humans have an anthropomorphic thinking towards animals and selfobject relationship with animals (Serpell, 2003; Brown, 2007). Therefore, most humans can be attracted strongly by animals, and feel getting a sort of social support from animals (Garrity and Stallones, 1998).

Dog ownership has attracted attention because the attachment formed between dogs and their owners has been shown to affect the

* Corresponding author. Fax: +81 42 769 1853.

E-mail address: kikusui@azabu-u.ac.jp (T. Kikusui).

health of the owner (e.g. Stallones et al., 1990). The results of animal experiments, including those using primates, show that, under stressful conditions, the existence of a partner to which the subject shows attachment and bonding brings buffering effects (Kikusui et al., 2006). However, alterations in the function of the human neuroendocrine system resulting from interactions between humans and dogs remain unclear.

The influence of interaction with animals has been determined to be a “stress buffering effect”. For example, interaction with animals reduces loneliness or depression, and stress reactions as assessed by psychological indexes (Gilbey et al., 2007; Souter and Miller, 2007) and by physiological parameters such as catecholamines and cortisol (Barker et al., 2005) respectively. However, these measurements may not be optimal to evaluate positive relationships between humans and dogs. Oxytocin (OT) is a peptide hormone synthesized in the magnocellular neurosecretory cells of the supraoptic and paraventricular nuclei of the hypothalamus, and is released during lactation and parturition. During the stress response, OT decreases activity of the hypothalamic–pituitary–adrenal axis (Amico et al., 1994; Windle et al., 1997; Neumann, 2002). It has also been related to social affiliation behaviors: the OT concentration in cerebrospinal fluid is positively correlated with social behavior in rats and monkeys (Haller et al., 1996; Winslow et al., 2003) and OT injected into the brain induces social grooming (Pedersen et al., 1988). It has also been shown that OT plays an important role in pair bonding (Panksepp, 1992; Carter, 2003; Lim et al., 2004) and social affiliation and trust (Witt et al., 1992; Kosfeld et al., 2005). Moreover, recent findings suggest that central OT is released in response to physical contact in mice (Uvnas-Moberg, 1997). In humans, intranasal administration of OT has been shown to calm depressive tendencies and anxiety. (Born et al., 2002; Heinrichs et al., 2003). Moreover, intranasal administration of OT increased gaze specifically toward the eye region of human faces (Guastella et al., 2008). However, it is unclear whether OT is related to social attachment or not in the human. It has been shown that the plasma OT concentrations in humans and dogs increase after interactions (Odendaal and Meintjes, 2003). However, behavioral components involved in interactions have not been analyzed, and thus, behavioral indexes that probably cause increase in OT levels remain unknown.

In this study, we focused on the dog's gaze, and framed a hypothesis that the concentrations of OT in the urine of dog owners are affected by their dog's gaze, which functions as an attachment behavior. To test this hypothesis, the urinary OT concentrations of dog owners were measured before and after 30-minute interactions with their dogs.

Methods

Participants

This study involved fifty-five volunteers (male: $n=21$, 36.0 ± 13.5 years old; female: $n=34$, 39.9 ± 13.9) and their dogs (supplemental data). They were recruited in dog training classes. They were aware of the procedure of the experiment but blind to its purpose. All participants were healthy and not on prescription medication. Gathering from information in prior recruiting explanation and before and after experiments, it was supposed that they were average Japanese in term of socioeconomic status and intelligence.

The study was approved by the Ethics Committee of Azabu University, Japan. Informed written consent was obtained from each participant.

Questionnaire

Prior to the experiment, we mailed questionnaires to participants to investigate the degree of relationship with their dogs. The

participants were asked their age and sex, their experience of dog ownership, such as their age when they owned their first dog, duration of dog ownership, and the total number of dogs that they had owned, and any medicines they were taking. We also investigated the participants' degree of relationship with their dogs by asking two questions: “How much are you satisfied with your dog?” and “How much do you feel you can communicate with your dog?” that were answered on a 5-point scale. The participants were also asked to furnish information about their dogs, such as breed, current age, sex (neutered/spayed) of the dogs, their age when they were adopted as pets; and the duration of ownership.

Experimental procedures

Experiments were conducted in an experimental room (6×4.5 m) at Azabu University. A chair was set in the middle of the room, and a video camera (GZ-MG40, Victor, Kanagawa) was positioned by the wall to record behaviors of dogs and their owners. Two types of experiment were carried out per participant on separate days. All the experiments were conducted from 1400 h to 1700 h; participants were asked to avoid eating and drinking for 2 h beforehand. An hour before each experiment, participants urinated at home.

Experiment 1 (interaction experiment)

Experiment 1 consisted of three settings: 20-minute rest (REST-1), 30-minute testing period involving usual interaction with the dog (INT), and 20-minute rest after INT (REST-2). First, on arrival, the participant was taken alone to the experimental room, and was asked to rest on the chair during REST-1. In the meantime, his/her dog was kept waiting in another room with an experimenter. The blood pressure and heart rate of the participant were measured. The participant was requested to provide a urine sample after REST-1. Subsequently the dog was allowed to enter the experimental room and sniff around before INT.

During INT, the participant was instructed to remain sitting on the chair to prevent the behavior being influenced by physical activity. In order to prompt their behavior during INT, the participant was instructed to ask his/her dog to sit on the floor every 3 min for five times. The timing was controlled by a knock on the door from outside. The procedure of INT was explained to the participant, and each participant was informed that he/she would not be judged on the success rate of the commands. The participant was forbidden to give his/her dog food or toys as a reward. Except for these instructions, the participant was able to interact freely with his/her dog. After INT, the dog was removed from the room and the blood pressure and heart rate of the participant were measured. After REST-2, a further urine sample was collected from the participant.

Experiment 2 (control experiment)

We conducted another experiment, in which behavior during INT was restricted so that participants were forbidden to look at their dogs directly. Experiment 2 was carried out using the same procedure as Experiment 1 in a different setting. A table and chair was placed near the wall of the experimental room, and the participant sat facing the wall. The participant interacted with his/her dog in the same way as in Experiment 1, including the one cue every 3 min for five times, but he/she was forbidden to gaze directly at their dog.

Experiment 3 (opposite-order experiment)

In order to assess possible influence of the order of experiments on the experimental results, we performed an additional experiment, wherein the interaction and control experiments were performed in opposite order (i.e., control experiments were performed before interaction experiments).

Assessment

Behaviors of owners and their dogs

We observed the durations of several behaviors: “dog’s gaze at owner (dog’s gaze),” “dog’s touch of owner (dog’s touch),” “owner’s touch of dog (owner’s touch),” “owner’s talk to dog (owner’s talk),” and the frequency of owner’s talk during INT. Because the active interactions between owners and their dogs were observed in the first 5 min of a 30-minute INT in most cases, the behaviors in the first 5 min which had been recorded by a video camera were analyzed by two persons who were blind to details of this study. The scores by the two observers were highly correlated ($r_s=.82$). We analyzed behavioral exchanges, comprising each behavior and response, between participants and dogs as one bout if there was an interval of more than 3 s before the next bout. Each exchange bout was scored by the behavior that initiated it.

Measurement of human urinary oxytocin

Urine was collected from participants just before INT and after REST-2. Immediately after collection, urine samples were centrifuged at 4 °C in a refrigerated centrifuge, and frozen at –80 °C until assay. Urinary OT concentrations were measured by radioimmunoassay (Onaka et al., 1988; Onaka and Yagi, 1990). Creatinine concentrations were measured using a kit (Creatinine test, Wako, Osaka). Urinary OT levels are expressed as the OT to creatinine ratio.

Further, in the opposite-order experiment (experiment 3), we measured the concentration of AVP—another nanopeptide released from the posterior pituitary, similar to OT by radioimmunoassay (Onaka et al., 1988; Onaka and Yagi, 1990). The AVP concentration was corrected with creatinine concentration.

Measurement of human blood pressure and heart rate

The blood pressure and heart rate of participants were measured just before and after INT using a digital automated sphygmomanometer (HEM-650, Omron, Kyoto).

Statistical analysis

Statistical analyses were performed by three-way ANOVA with repeated measures and two-way ANOVA, and if significant differences were shown, the Bonferroni method was used for post hoc analysis. The relationships between the variables were examined by the Wilcoxon signed-ranks test, Mann–Whitney’s *U*-test, Pearson product-moment correlation coefficient (two-tailed) and Spearman’s rank correlation coefficient (two-tailed). Results were expressed as median±quartile (non-parametric) or mean±SE (parametric) (SPSS v.14.0).

Results

Cluster analysis of duration of dog’s gaze and degree of owner’s relationship with dog

Plotting histograms for each behavior revealed that the duration of dog’s gaze had two peaks (Fig. 1a). Formation and maintenance of social attachment between owners and their dogs are considered to be related to the various mutual communicative behaviors of dogs (Albert and Bulcroft, 1987; Voith, 1985). Therefore, based on the degree of relationship shown, we divided participants by a hierarchical cluster analysis using three factors: the duration of dog’s gaze in the experiment, and responses regarding the degree of communication and satisfaction with their dogs from the participant’s questionnaire. Visual examination of the dendrogram showed that participants could be divided into two separate groups (Fig. 1b). The number of participants in each group was as follows: Group 1 $n=13$

(male: $n=3$, female: $n=10$, 52.8 ± 4.0 years old), and Group 2 $n=42$ (male: $n=18$, female: $n=24$, 41.51 ± 2.72 years old). When the two variables from the questionnaire and duration of dog’s gaze were compared between the two groups by Mann–Whitney’s *U*-test, significant differences were found between Groups 1 and 2 in the degree of communication, $p<.001$; the degree of satisfaction, $p<.01$; and the duration of dog’s gaze (s), $p<.001$ (Fig. 2). Group 1, who reported a higher degree of satisfaction and communication and longer dog’s gaze, was named the Long Gaze Group (LG). Group 2, who reported a lower degree of satisfaction and communication with their dogs and showed a shorter duration of dog’s gaze, was named the Short Gaze Group (SG). The breed, current age, and sex of the dogs; their age when they were adopted as pets; and the duration of ownership were not significantly different between LG and SG (breed: $\chi^2(3)=11.04$, $p=.61$; sex: $\chi^2(3)=2.14$, $p=.54$; current age: $U=218.00$, $p=.70$; age when adopted as pets: $U=232.50$, $p=.97$; duration of ownership: $U=222.00$, $p=.58$; Table 1).

Comparing the success ratio of command by owners, there was no significant difference between LG and SG (LG=.80±.10, SG=.84±.05, $p=.69$). Other behavioral variables except for Owner’s Touch ($r=-.337$, $p<.05$) also were not significantly correlated with the success ratio of command.

Differences in each variable between the two groups in Experiments 1 and 2

Oxytocin

For the comparison of urinary OT concentrations, a three-way ANOVA with repeated measures was conducted using the factors “groups” (LG and SG), “time of urine collection” (pre and post), and “experiment” (1 and 2). There was a statistically significant interaction between groups and times ($F(1,84)=9.03$, $p<.01$). Using post hoc Bonferroni methods, in Experiment 1 the OT concentrations after INT were shown to be significantly higher in LG than in SG ($p<.01$, Fig. 3).

Behaviors of owners and their dogs

A two-way ANOVA was conducted on the factors “group” (LG and SG) and “experiment” (1 and 2) for each behavior variable. For the duration of dog’s gaze, interaction between the factors was significant ($F(1, 109)=28.60$, $p<.001$). There were significant differences between experiment 1 and 2 in total and in LG (both $p<.05$), but there was no significant difference in SG between experiments 1 and 2. For other behaviors, significant differences were seen between experiments 1 and 2 in both LG and SG, except for duration of dog’s touch in LG and owner’s touch in LG (Table 2).

Blood pressure and heart rate of owners

There were no significant differences between values of blood pressure and heart rate of participants before and after INT (BP: pre $127.84\pm1.74/80.69\pm4.38$, post $128.52\pm1.84/79.53\pm1.15$ mmHg; HR: pre 73.75 ± 0.04 , post 70.05 ± 1.96 bpm).

Association between OT levels, behavior variables and questionnaires responses

By Spearman correlation analysis, the increase in OT in response to INT was correlated with the frequency of exchange bouts initiated by dog’s gaze in LG in experiment 1 ($r_s=.73$, $p<.01$), but not in SG (Fig. 4). In contrast, there was a negative correlation between the increase in OT and the duration of owner’s talk in SG (Table 3).

The owner’s age was positively correlated with the increase in OT in LG, but was negatively correlated in Total. The age at owning the first dog had a negative correlation with the increase of OT in Total. There was no significant sex difference (data not shown). On the other hand, there were no significant correlations between the

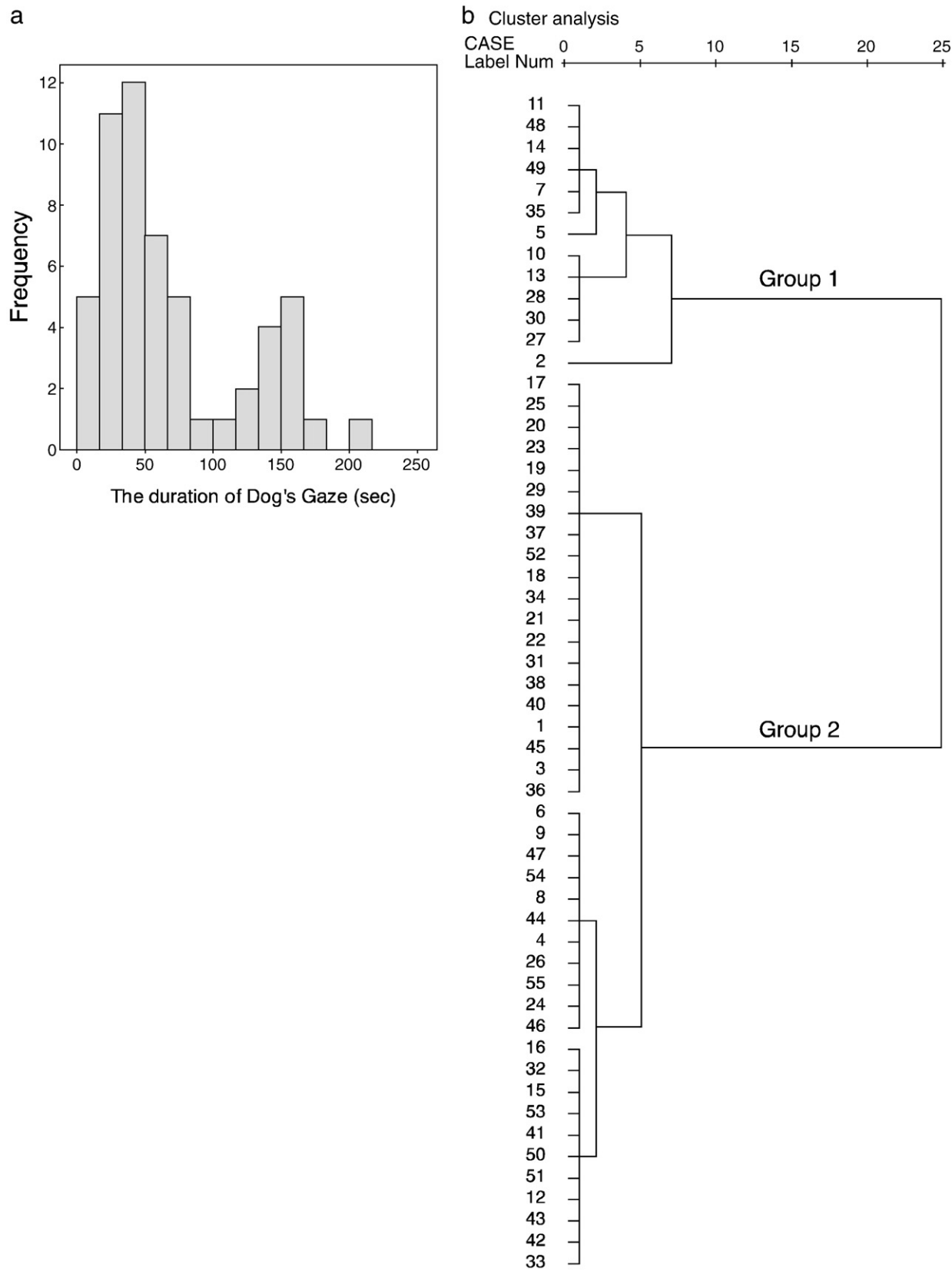


Fig. 1. (a) The histogram of the duration of dog's gaze in experiment 1 showed two peaks at around 100 s. (b) Participants were divided into two separate groups by a hierarchical cluster analysis using three factors (degree of satisfaction and communication with their dogs, and duration of dog's gaze).

increase in OT levels and the current age of the dogs, their age when they were adopted as pets, and the duration of ownership (Table 3).

In experiment 3, a very strong positive correlation was observed between the duration of a dog's gaze and the increase in the owner's urinary OT levels in the interaction experiments ($r_s=0.86$, $p<0.01$;

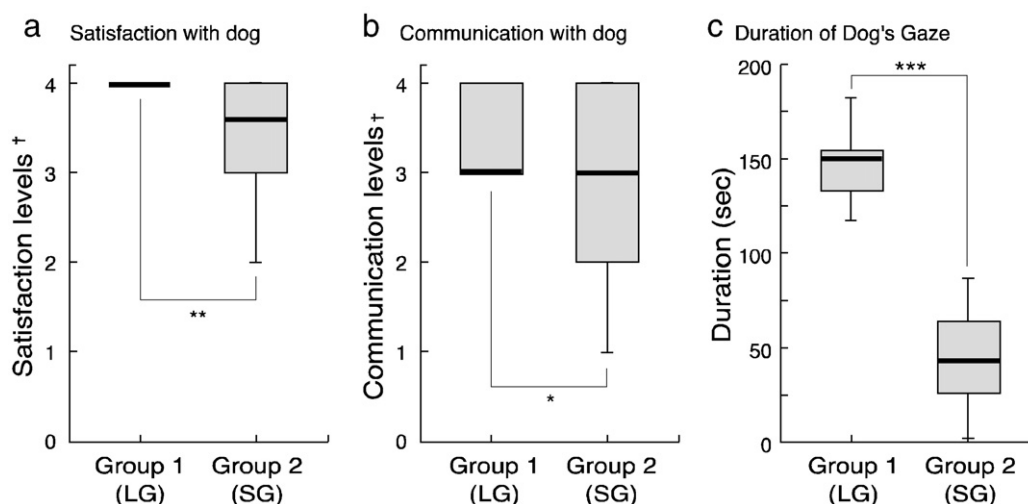


Fig. 2. Two groups obtained by cluster analysis were compared with respect to each factor (Mann–Whitney's *U*-test). Group 1 was a higher degree of satisfaction and communication with their dogs, and showed a longer dog's gaze. Group 2 was a lower degree of satisfaction and communication, and a shorter duration of dog's gaze. These were named the Long Gaze Group (LG) and the Short Gaze Group (SG) respectively. * $p < .05$, ** $p < .01$, *** $p < .001$, †5-point scale: 4 = very much, 3 = a fair amount, 2 = somewhat, 1 = a little bit, 0 = not at all.

Fig. 5a) but not in the control experiments. There was no significant correlation between AVP concentrations and the duration of a dog's gaze (Fig. 5b).

Discussion

Beneficial effects on the physical and mental health of humans have been shown to result from the building of affectionate relationships with dogs (Ory and Goldberg, 1983; Garrity et al., 1989). To our knowledge, the present study is the first to investigate whether human neuroendocrinological systems react to specific social cues from other species. In this study, the hypothesis that the concentration of OT in the urine of dog owners could be changed in response to their dogs' gaze, representing a kind of social attachment, was examined. The participants were divided into two groups according to the degree of their relationship with their dog and the duration of the dog's gaze. The group of owners who received dog's gazes over a longer duration (LG) had a better relationship with their dogs, and showed a higher concentration of urinary OT than the SG group. These results show that the level of OT in humans may be related to attachment behavior, and urinary OT could be used as a non-invasive psychoneuroendocrinological indicator of the relationship between humans and dogs.

Two experiments were carried out: in experiment 1, the dog and owner were given a 30-minute test period for usual interaction; in experiment 2, the owner was instructed not to look at his/her dog directly during the test period. In the results of experiment 1, urinary OT levels after interaction were significantly higher in LG compared with SG. OT concentrations tended to increase after interaction with dogs in experiment 1, as analyzed by Wilcoxon paired test (a single statistical comparison between pre- and post-interaction OT levels, $p < .01$). Although dog's gaze in LG also decreased significantly in experiment 2, no significant difference was observed in the duration

of dog's gaze between experiments 1 and 2 in SG (Table 2). This was in agreement with the OT concentration results. Regarding the relationship between each behavior and the increase of OT in experiment 1, dog's gaze and dog's touch were correlated with an increase of OT in LG, whereas no correlation was found between human behaviors and increase of OT in SG. From these results, urinary OT concentration in the owner is assumed to be associated with the dog's gaze and touch (Table 3). In the present study, interaction experiments were performed before the control experiments. In order to assess possible influence of the order of experiments on the experimental results, we performed an additional experiment, wherein the experiments were conducted in opposite order. We obtained the same results as obtained previously (Fig. 5a). Therefore, the increase in OT levels was not due to adaptation to the experiments because of repetition. Further, we analyzed the relationship between AVP concentrations and the duration of a dog's gaze. There was no significant correlation between the 2 parameters, indicating that the increase in OT levels in response to a dog's gaze was specific and not due to the artifacts of experimental procedures (Fig. 5b).

Although it is unclear whether dogs form social attachments to humans, dogs do show attachment-like behaviors to humans (Topál et al., 1998), and humans perceive them to be like infants. Each animal

Table 1

The information of dog of two groups obtained by cluster analysis. There were no significant differences among two groups (Mann–Whitney's *U*-test)

	LG	SG
	Mean ± SE	Mean ± SE
Current age (years)	7.63 ± 4.38	3.81 ± .29
Age when they were adopted as pets (months)	7.46 ± .98	7.62 ± 4.38
Duration of ownership (months)	47.32 ± 4.18	50.08 ± 24.46
Sex		
Male (neutered)	7 (6)	26 (21)
Female (spayed)	6 (4)	16 (10)

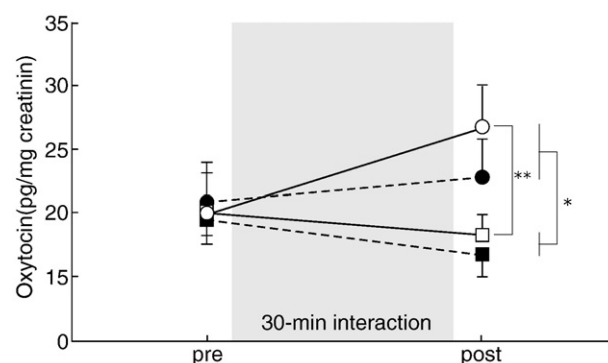


Fig. 3. The urinary OT concentrations of the dog owners were measured before and after the interactions with their dogs in experiment 1 (usual interaction) and experiment 2 (control). A three-way ANOVA with repeated measures and post hoc Bonferroni analysis were conducted. In experiment 1, OT concentrations after interaction with the dogs were significantly higher in LG than in SG, and the total OT level in both experiments 1 and 2 was also significantly higher for LG than for SG. —○— Exp.1 LG —□— Exp.1 SG —●— Exp.2 LG —■— Exp.2 SG. * $p < .05$, ** $p < .01$.

Table 2

Most behaviors, except duration of dog's gaze in SG and dog's touch and owner's touch in LG, showed significant differences between experiments 1 and 2 (Wilcoxon's paired test)

Behavior	Factor (Group : Exp. 1 vs. Exp.2, mean $\pm$ SE)
Dog's gaze (s)	Total : 95.56 $\pm$ 4.57 vs. 48.24 $\pm$ 6.52*
	LG : 148.79 $\pm$ 7.89 vs. 58.89 $\pm$ 11.61*
	SG : 42.34 $\pm$ 4.61 vs. 37.58 $\pm$ 5.93
Dog's touch (s)	Total : 17.15 $\pm$ 4.31 vs. 4.30 $\pm$ 6.15**
	LG : 17.62 $\pm$ 7.44 vs. 6.30 $\pm$ 10.95
	SG : 16.68 $\pm$ 4.35 vs. 2.31 $\pm$ 5.59**
Owner's touch (s)	Total : 108.83 $\pm$ 9.24 vs. 36.64 $\pm$ 13.18***
	LG : 102.46 $\pm$ 15.95 vs. 44.72 $\pm$ 23.48
	SG : 115.20 $\pm$ 9.33 vs. 28.57 $\pm$ 11.99***
Owner's talk (s)	Total : 43.10 $\pm$ 3.51 vs. 12.06 $\pm$ 5.01***
	LG : 45.65 $\pm$ 6.06 vs. 14.09 $\pm$ 8.92*
	SG : 40.56 $\pm$ 3.54 vs. 10.02 $\pm$ 4.56***
Owner's talk (times)	Total : 66.31 $\pm$ 4.91 vs. 19.63 $\pm$ 5.94***
	LG : 75.00 $\pm$ 8.68 vs. 22.00 $\pm$ 10.63*
	SG : 57.63 $\pm$ 4.60 vs. 17.25 $\pm$ 5.32***

* $p < .05$.

** $p < .01$.

*** $p < .001$.

has species-specific cues for social bonding; visual cues are one of the most important cues in humans. It has been reported that pictures of the face of a loved one or of one's own children deactivate the amygdaloid nucleus (Bartels and Zeki, 2004). Humans depend on visual information, especially eye movement, to communicate emotional status (Kawashima et al., 1999; Langton, 2000). In contrast, few studies have focused on the role of a dog's gaze. Because the ears, tail, fur, and other facets of the appearance of dogs have been artificially selected during domestication, olfactory information has been considered to provide more important cues than visual information in this species (Bradshaw and Brown, 1990). For this reason, their visual abilities have been rather underestimated. In recent years, however, the social cognitive abilities of dogs have received attention. Visual communication abilities have been considered to have developed in dogs following domestication and to be related to the coordinated behavior required for living with human beings. As evidence of this, it has been shown that dogs change their behaviors depending on the orientation of human faces or eye closing motion

Table 3

Using Spearman rank correlation analysis, the increase in OT concentration was correlated with the frequency of exchange bouts initiated by dog's gaze in LG (see Fig. 4a), and OT was correlated negatively with the duration of owner's talk in SG

		The increase of oxytocin (post-pre)		
		LG	SG	Total
Behavior	Dog's gaze	.60 [†]	-.09	.16
	Dog's touch	.54*	-.19	.00
	Owner's touch	.24	.15	.17
	Owner's talk	.17	-.30**	-.17
	Owner's talk	-.25	-.13	-.06
Frequency	Dog's gaze	.73**	.03	.27*
Frequency of bouts	Dog's touch	.33	.07	.22
	Owner's touch	.40	.04	.18
	Owner's talk	.36	-.27	.00
Questionnaire				
Owner's age		.65*	.04	-.44**
Dog's current age		.09	.09	.17
Dog's age when they were adopted as pets		.46	.10	.12
Duration of ownership		.32	.11	.08
Age owning the first dog		-.15	-.17	-.60***
Number of dogs owning in the past		.16	.01	.32
Duration of dogs owning in the past		-.38	.12	.52
Degree of communication with dogs ^a		-.52	-.03	.04
Degree of satisfaction with their dogs ^a		^b	.03	-.14

The owner's age in LG was correlated positively with the increase in OT, and the age at owning the first dog had a negative correlation with the increase in OT in SG.

* $p < .05$, ** $p < .01$, *** $p < .001$, [†] $p = .054$.

^a 5-point scale (see Fig. 1).

^b Not determined.

(Gácsi et al., 2004; Virányi et al., 2004). When faced with a difficult task, domestic dogs quickly gave up the task and looked at their owners whereas wolves tried to solve the problem on their own (Miklósi et al., 2003). According to these findings, it is not surprising that the dogs gazed at their owners for a shorter duration in Experiment 2 when the owners were asked to show their backs to the dogs. It is not clear whether a dog's gaze at its owner is innate or learned, or whether the dog's gaze has different functional meanings in relation to the human and conspecifics. However, the reason for the response of humans to attachment-related signals from other species

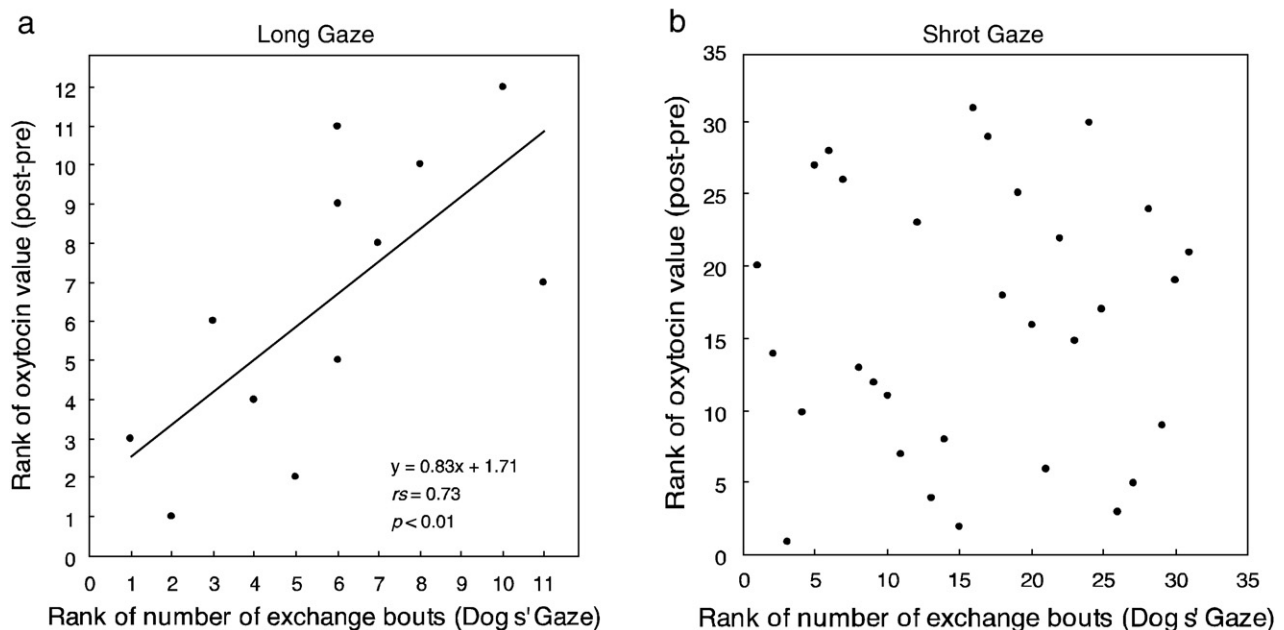


Fig. 4. The numbers of exchange bouts initiated by dog's gaze to owner were significantly correlated with the difference between post and pre of urinary OT values in LG (a), but not in SG (b).

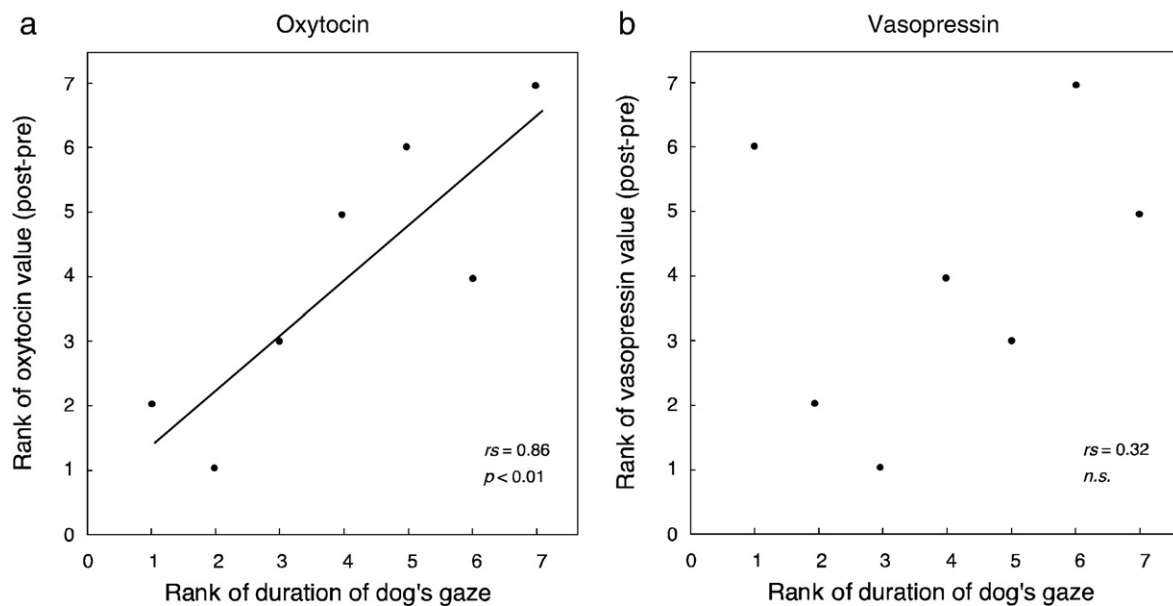


Fig. 5. In experiment 3, the interaction and control experiments were performed in opposite order (i.e., control experiments were performed before interaction experiments). A very strong positive correlation was observed between the duration of a dog's gaze and the increase in the owner's urinary OT levels in the interaction experiments ($r_s = 0.86$, $p < 0.01$). There was no significant correlation between AVP concentrations and the duration of a dog's gaze (Spearman's correlation coefficient by rank test).

can possibly be explained by the human nature. Humans tend to anthropomorphize other animals and objects (Salmon and Salmon, 1983; Albert and Bulcroft, 1987). Human infants react to the motion of a robot showing communicative gaze (Itakura et al., 2008). One can assume that such behavior is very similar to that of a human child, so that an owner who is gazed upon by their dog perceives an emotional condition of the dog and regards the gaze as an attachment behavior. Therefore, in this study, a dog's gaze was considered to be a significant cue for social contact for humans.

The results of this study highlighted that there was a high correlation between the frequency of exchange bouts initiated by the dog's gaze and an increase of urinary OT concentration in the LG group (Fig. 4). A dog's gaze can be considered as an attachment behavior that elevates the OT levels of the owner. When considering the negative correlation between talking by the owner and the increase in OT levels for SG, it is assumed that attachment behaviors were not established proactively if the owner often initiated the exchange with dogs. Consistent with this view, the manners and frequencies of a mother's approach toward her infant influence the infant's behavior and the mother–infant relationship (Isabella et al., 1989; Smith and Pederson, 1988). Thus, the less attachment between the dog owners and their dogs in SG was considered to be due to the owners' behavior. However, from a contradictory viewpoint, it is possible that the owners' talk in SG might have increased because of the less attention given to them by their dogs. In any case, it is likely that the behavior of the dogs did not satisfy the owners sufficiently. In this study, although the contribution of touching cannot be excluded completely, the frequency of exchanges initiated by touching was not significantly correlated with the increase of OT, in contrast to the high correlation between dog's gaze and OT. The result that OT concentrations were affected by whether dogs or owners initiated exchange bouts indicates that a dog's gaze meets the requirement for an attachment behavior.

The urinary OT concentrations of the owners measured in this study revealed other findings, in addition to the relationship with a dog's gaze. Regarding the relationship between the owner's age and the increase in OT concentration, a positive correlation was observed for LG who had a higher mean age than SG, but not for SG (Table 3). On the contrary, a significant negative correlation of age at owning the first dog with the increase in OT concentration was not found in LG but

in Total (Table 3). It is said that a caregiver's responsiveness to attachment behavior greatly depends on his/her experiences (Bowlby, 1969; Ainsworth and Eichberg, 1991), such as the maternal environment and experience of raising children. At present, it is unclear whether the OT responsiveness is related with the age and social experiences of caregivers (owners with dogs). Further research is needed to clarify these issues. In addition, we did not examine the socioeconomic status and intelligence of the participants in detail, since no considerable differences exist among the Japanese with respect to these factors. However, Ory and Goldberg (1983) have reported that a subject's social status affects the psychological effect of dog ownership. Therefore, it may be necessary to consider the influence of personal factors such as socioeconomic status, education, race, and religion in other countries.

The results of this study suggest that of all the interactions observed between a dog and its owner, the dog's gaze, as a factor that contributes to social bonding, has a particularly strong effect on the neuroendocrine system of the owner. In humans, only indirect findings on the relation of OT secretion to attachment have been reported (Fries et al., 2005). It is not yet clear whether OT concentrations in urine reflect the activity of the central nervous system; however, it has been shown that there is a strong positive relationship between the OT concentration in urine and that in plasma, and plasma OT is related to the activity of the hypothalamus. The urinary OT excretion increased with intravenous administration of OT. Less than 1% of OT was cleared in urine, and the rate of urinary OT excretion per creatinine closely correlates with plasma OT concentration ($r = 0.89$, Amico et al. 1987), indicating that urinary OT levels reflect plasma OT levels. Electrical stimulation of the hypothalamic oxytocin neurons facilitated OT release within the hypothalamus as well as that into the plasma (Jones et al., 1983). Physiological stimuli, such as systemic hyperosmolality, also induce OT release in both the hypothalamus and plasma with different time course (Ludwig et al., 1994). From all these data it is likely that urinary OT, at least to some extent, reflects the hypothalamic oxytocinergic activity. OT may therefore be a useful non-invasive indicator for use in the study of the attachment between humans and animals. Moreover, it has been shown that administration of OT to humans increases their trust for others (Kosfeld et al., 2005) and decreases their depressive tendency and anxiety (Born et al., 2002; Heinrichs et al., 2003). The

physiological role of OT released by a dog's gaze remains to be clarified in future experiments. In this study, there were no significant differences in the pre- and post-interaction OT levels, although the OT levels tended to increase in LG. This result could be due to the timing of urine sampling.

This study has revealed a clue to the neural mechanisms by which association with dogs affects the physical and mental health of humans. It is said that animals have species-specific styles of attachment. This study suggests that humans and dogs may have a common style of attachment, and this may partially explain why dogs can adapt to human society.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.yhbeh.2008.12.002.

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