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Neurophysiological Correlates of Affiliative Behaviour between Humans and Dogs

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SUMMARY

Few physiological parameters for positive human–companion animal contact have been identified and those that are established have all been in humans. The implication is that if the physiological reactions are mutual, dogs would experience the same psychological benefits from these neurophysiological changes as humans. Therefore, we have determined the role of certain neurochemicals during affiliation behaviour on an interspecies basis. Our results indicate that concentrations of β-endorphin, oxytocin, prolactin, β-phenylethylamine, and dopamine increased in both species after positive interspecies interaction, while that of cortisol decreased in the humans only. Indicators of mutual physiological changes during positive interaction between dog lovers and dogs may contribute to a better understanding of the human–animal bond in veterinary practice.

KEYWORDS: Neurochemicals; parameters; positive human–dog interaction.

INTRODUCTION

In 1929 it was shown that when a human strokes a dog the mean arterial blood pressure (MAP) of the dog declines (cited by Cusack & Smith, 1984). More than 50 years later it was shown that blood pressure in humans also decreases during such positive interaction with dogs (Katcher *et al.*, 1983). As an increase in sympathetic nervous system activity is associated with stress and an increase in MAP, the decline in blood pressures brought about through positive human–animal contact is suggestive of a decrease in sympathetic activity and a de-stressing experience (Ganong, 1995).

An experiment was designed to investigate the neurochemical and hormonal correlates for human–dog affiliation behaviour based on available knowledge of neurochemical changes during affiliation behaviour. The hypothesis was that a specific plasma profile of neurochemicals and hormones underlies the physiological responses associated with overt positive human–dog interaction. The decision to choose plasma concentrations of β-endorphin, oxytocin, prolactin, β-phenylethylamine, dopamine, and cortisol for monitoring was based on previous research in this area (Carter *et al.*, 1997; Liebowitz, 1983).

On the assumption that the decline in blood pressure in both humans and animals is also, by extension, an indicator of positive human–dog interaction, we used it as an indicator of the timing to take blood samples for analysis of the selected plasma variables.

SUBJECTS AND METHODS

Eighteen adult, human Caucasian subjects (eight males and 10 females, aged 19–55 years [average 30 years]) participated on a voluntary self-selected basis. It was required that they all possessed feelings of affection towards dogs. Individuals were healthy and not on prescription medication. Eighteen adult canine subjects (seven males, three castrated males; 11 females, five spayed) were selected on the basis that they were known to have placid temperaments and were used to human contact as prescribed for the interaction. Some dogs belonged to the participants and some dogs were provided to non-owners. Fe-

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males were not in oestrus. To facilitate blood sampling from the cephalic vein, only dogs weighing more than 15 kg were included in the trial. The group consisted of nine Beagles, two Border Collies, one Bull Dog, one Cocker Spaniel, one Dachshund, three Labradors, and one Staffordshire bull terrier and their ages varied between two and 11 years (average 6.4 years). The dogs were healthy and none was on prescription medication.

The experimental model consisted of a single group of humans ($n = 18$) each interacting in a positive way with a dog. A basic experimental design, consisting of pre- and post-test values, was used (Dane, 1990). Each individual was his/her own control, i.e., the post-interaction value of a variable was compared with its pre-interaction value in the same individual. This was done in order to eliminate the effect of biological variation between individuals. The external control consisted of quiet book reading in the same environment, using the same methods as for positive dog interaction, but at another time. Blood pressure measurements and blood sample collections were made by a medical nurse in the case of the human subjects and by a veterinary physiologist in the case of the canine subjects.

Mean arterial pressure was measured using an automatic Dinamap, TP Blood Pressure Unit (Critikon, Vital Signs Monitor, 1846SX). The apparatus was applied to the non-active arm of the human, and the tail base in the case of the dog (Bodey & Mitchell, 1996; Yeates & Odendaal, 1998).

Venous blood samples were collected by venous puncture from the right cephalic vein in both humans and dogs. The 10 mL samples were collected in heparinised vacu-tubes to which specific enzyme inhibitors were added, *viz.* aprotonin and soya bean trypsin inhibitor (Sigma–Aldrich). The inhibitors prevented the enzymatic breakdown of the peptide neurochemicals after collection.

On arrival, participants were taken to a room, which was empty apart from two tables for the blood pressure apparatus and blood collection material, respectively, and two chairs, one for the medical nurse and one for the veterinary physiologist. Room lighting was natural. The human subjects sat on blankets on the floor to optimise their interaction with the dogs. Blood samples were collected from the humans as well as the dogs in this position, and with the minimal disturbance. Participants had about 10 min to adapt to the environment before samples and measurements for baseline values were taken. Five stable blood pressure readings over a 2 min period were used to establish the baseline value. Interaction with the dogs started after samples for baseline values had been collected. The interaction consisted of social gestures only. These included talking softly to the dog, gently stroking the dog with long smooth strokes, low-key playing with the dog and scratching its body and ears. During this time the human's attention was completely focused on the dog. Blood samples during the interaction were taken at a time when five stable blood pressure changes equivalent to a decrease of 5–10% from the control value, could be demonstrated over a 2 min period. It was decided prior to the experiment that a maximum of 30 min would be allowed for a suitable decrease in blood pressure.

Immediately after collection, blood samples were centrifuged at 4 °C in a refrigerated centrifuge. The plasma so obtained was analysed for concentrations of β-endorphin, oxytocin, prolactin, the β-phenylethylamine metabolite phenyl acetic acid, dopamine, and cortisol, by using a high-performance liquid chromatography (HPLC) technique (Varian 9065, SMM) with a polychrome diode array detector (Lehmann & de Beer, 1998). In a pilot study (Lategan *et al.*, 1998), it was found that serum levels of β-phenylethylamine were very low making detection difficult, and therefore the catabolite of this neurotransmitter, *viz.* phenyl acetic acid was determined.

The null hypothesis that the median difference between the measurements before and after interaction is zero was tested at the 5% level of significance ($p < 0.05$). A statistically significant difference between baseline and post-intervention values of the neurochemical parameters would therefore, result in a rejection of the null hypothesis without specification of the direction of the difference. The direction of change could, however, be observed in the data. The median difference was used. Statistical analysis was done according the Wilcoxon signed rank test for symmetry, because of the relatively small sample (Steyn *et al.*, 1994).

The Ethics Committee of the University of Pretoria approved the research protocol.

RESULTS

Mean arterial blood pressure tended to decrease in both species during positive interaction (Table I). The time taken for such decrease following the commencement of the session of interaction was between 5 and 24 min in all the humans and be-

Table I
Physiological correlates of positive human–dog interaction (n = 36)

Physiological correlates	*Human (n = 18) median (Interquartile range)*			*Dogs (n = 18) median (Interquartile range)*		
	Before	*After*	*p-value*	*Before*	*After*	*p-value*
Mean arterial blood pressure (mmHg)	87.6 (19.2)	84.4 (14)	$p < 0.01$	91.0 (33.2)	87.7 (16)	$p < 0.01$
Serum β-endorphin (pmol/L)	3.1 (5.4)	8.0 (6.5)	$p < 0.01$	1.2 (1.3)	2.8 (2.3)	$p < 0.01$
Serum oxytocin (ng/L)	2.1 (2.5)	4.0 (1.0)	$p < 0.01$	0.1 (0.4)	0.5 (1.0)	$p < 0.01$
Serum prolactin (ng/L)	9.2 (9.1)	11.6 (10.1)	$p < 0.01$	38.5 (40.0)	39.0 (45.0)	$p = 0.01$
Serum phenyl acetic acid (pg/L)	123.5 (4.0)	143.0 (8.0)	$p < 0.01$	54.5 (13.0)	91.5 (10.0)	$p < 0.01$
Serum dopamine (pg/L)	86.5 (7.0)	107.0 (9.0)	$p < 0.01$	35.0 (9.0)	60.5 (3.0)	$p < 0.01$
Serum cortisol (mmol/L)	317.0 (224.0)	309.0 (222.0)	$p < 0.01$	366.5 (202.0)	416.0 (248.0)	$p = 0.30$

tween 5 and 23 min in all the dogs. The average time for a decrease in blood pressure was 15 min.

With positive interaction, both species showed significant increases in plasma β-endorphin, oxytocin, prolactin, phenyl acetic acid, and dopamine. In the human participants there was a significant increase in prolactin ($p < 0.01$), but in the dogs there was the same tendency at a $p \leqslant 0.05$ significant level. Cortisol decreased in humans and tended to increase in dogs, but the difference between baseline and post-interaction samples was not significant in the dogs.

Although quiet book-reading (positive self-interaction) also produced similar changes as positive human–dog interaction, there were significant differences between the levels of increases of β-endorphin ($p < 0.01$), oxytocin ($p < 0.01$), and prolactin ($p < 0.01$), where the increases were higher during dog interaction than book reading (see Table II).

DISCUSSION

The results indicated that a significant decrease in blood pressure can be achieved between 5 and 24 min of positive interspecific interaction in both humans and dogs. Changes in plasma concentrations of the measured neurochemicals are similar in both humans and dogs. The assumption that a decrease in blood pressure could be an indicator of concurrent biochemical changes is supported. However, the decrease of blood pressure is is unlikely to be the cause of the chemical changes, but probably follows on the increase of oxytocin (Urnäs-Moberg, 1998). Positive dog interaction can be as relaxing as quiet book-reading, but dog interaction showed significant higher increases of the neurochemicals associated with bonding or affiliation.

Walsh (1991) considered the needs for nurturance, affiliation, and attachment to be 'rooted in the biology of the species'. Such needs can cross the species barrier as also indicated by the similar neurophysiological changes in both species. It has been hypothesised that companion animals can decrease anxiety and sympathetic nervous system arousal by providing a pleasant external focus for attention, promoting feelings of safety and providing a source of contact comfort (Friedmann, 1995). They can decrease loneliness and depression by providing companionship; promoting an interesting and varied lifestyle; and providing an impetus for nurturing (Katcher *et al.*, 1983). The results of this experiment, as indicated by the effects of the relevant neurochemicals, support such hypotheses.

Positive, affiliative emotions are not totally specific nor are they just non-specific arousal reactions. Rather, they involve highly individualised feelings of

Table II
Physiological correlates during quite book reading (n = 18)

Physiological correlates	*Humans (n = 18) median (Interquartile range)*		
	Before	*After*	*p-value*
Serum β-endorphin (pmol/L)	3.5 (6.7)	5.1 (6.4)	$p < 0.01$
Serum oxytocin (ng/L)	2.5 (2.0)	2.9 (2.0)	$p < 0.01$
Serum prolactin (ng/L)	10.2 (7.1)	10.4 (6.2)	$p < 0.01$

affiliation, which are biologically shaped. However, first reactions tend to occur instantaneously and involuntarily (Liebowitz, 1983). LeDoux (1998) described such emotions as biological functions (physiology) of the nervous system. This being so, there can be merit in monitoring neurochemicals to assist in our understanding of emotions. This approach contrasts with the more typical approach of studying emotions purely as psychological states, independent of the underlying brain mechanisms. Hatfield and Rapson (1993) proposed that most emotions have more similarities than differences with regard to the neurotransmitters or neuromodulators, which are involved in producing them.

On the basis that sympathetic nervous system activity dominates during the stress response, physiological effects of positive interaction between humans and animals have been measured, but in humans only. Physiological parameters such as changes in blood pressure (diastolic, systolic, and mean), plasma cholesterol and triglyceride concentrations, and skin conductance were monitored in order to determine their association with interaction effects (Friedmann, 1995).

β-Endorphin has been shown to be involved in learning and memory, feeding behaviour, thermoregulation, blood pressure regulation, and reproductive behaviour (Brown, 1994). An increase in plasma concentration of β-endorphin has also been associated with analgesia, euphoric states and destressful situations in humans (Bloom & Lazerson, 1988), and during affiliative grooming and sexual behaviour in monkeys (Keverne *et al.*, 1997). The current experiment confirms a significant rise in plasma β-endorphin concentrations in both humans and dogs interacting across the species barrier.

Oxytocin has been identified as a hormone, that promotes intimate bonding. Plasma oxytocin concentrations have been shown to increase with affiliative bonding in prairie voles (Gingrich *et al.*, 1997), bonding and attachment, social, maternal, sexual behaviour, and stress relief situations in rats (Urnäs-Moberg, 1997). Receptor areas located in the ventral medial nucleus, amygdala, and hypothalamus have been linked with joyous, affectionate, sexual, and reproductive behaviour (Hatfield & Rapson, 1993). In our experiment, oxytocin concentrations almost doubled in both humans and dogs after positive interaction between the species.

Generally, prolactin inhibits sexual behaviour and promotes bonding associated with parenting behaviour (Brown, 1994). Plasma prolactin has been shown to increase in plasma concentration with social bonding in chickens (Bekkedal & Panksepp, 1997), and with learning, maternal exposure to offspring, parental behaviour, and stress relief situations in rats (Sobrinho, 1993; Carter & Altemus, 1997). In this experiment, plasma concentrations of both humans and dogs increased when the two species interacted positively.

Phenylethylamine concentrations in urine were significantly higher in humans who were happily attached than in men and women undergoing a divorce (Sabelli *et al.*, 1990). Feelings of attraction, exhilaration, and apprehension have been associated with an increase of phenylethylamine in humans and rhesus monkeys (Liebowitz, 1983).

In this experiment, plasma concentrations of phenyl acetic acid – the metabolite of pheylethylamine – showed significant increases in both humans and dogs, suggesting an association in pleasurable interactions of this kind.

Humans with depressive illness show a decrease in brain noradrenalin and dopamine (Lambert *et al.*, 2000), whereas plasma dopamine concentrations has been shown to increase in association with pleasurable sensations, exhilaration, male copulation, feeding, and drinking (Mitchell & Gratton, 1994). The increase in plasma dopamine concentrations obtained in this study for both humans and dogs suggests that both participants derive 'pleasurable sensations' from their interaction.

Decrease in plasma cortisol concentrations were observed in prairie voles during encounters with strangers of the opposite sex, pair bonding, and stress relief situations (Carter *et al.*, 1997; Meyer *et al.*, 1997). Glucocorticoids are generally released during stress (Brown, 1994), so a decrease in plasma cortisol concentrations can be expected during stress relief. Only human participants showed a significant decline of cortisol during this experiment. The lack of a corresponding decline in plasma cortisol concentration in dogs may have resulted because some dogs found the new environment initially stimulating or stressful.

Although the need for positive interaction already exists in the basic behavioural patterns of many living organisms, attention-seeking behaviour only becomes clearly identified in advanced and well-developed social systems as a universal emotional need. Attention-seeking behaviour could be associated with problematic behaviour in humans and social animals. To distinguish between the concept as a normal emotional need and that associated with problematic behaviour a Latin term, *attentionis egens*, was introduced. This term describes the need for attention on a normal, basic emotional level as a prerequisite for successful social interaction. Deviations from the norm may be varied and manifest themselves as withdrawal from attention to a myriad of behavioural patterns aimed at getting excessive attention. Positive or affiliation interaction is seen as behaviour which is mutually beneficial, while negative interactive behaviour is harmful or constitutes a bad experience to one or both parties (Odendaal, 2000).

Social systems and positive interactions can be intraspecifics (i.e., between members of the same species), and interspecific (i.e., between members of different species). An outstanding example of such interspecies relationship is that between humans and companion animals. The success of human-companion animal interaction is probably mainly based on a two-way fulfilling of *attentionis egens*. Animal species traditionally thought of as suitable for human companionship are generally highly social, but less social animals can still fulfil the need for attention of their human owners. The greater the need for attention or the more social behaviour an animal exhibits, the more successful the bonding between human and animal can be.

Beneficial interaction between two social species can be described as a social symbiotic relationship (mutualism on a social level). In this regard the interaction between humans and dogs is a prime example. The dog can justly be seen as a prototype of companion animals (Odendaal, 2000).

The results of this experiment support a physiological basis of *attentionis egens* in human–dog affiliation. It is suggested that this information might be useful in veterinary practice, and should contribute to an understanding of the client–patient bond.

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